FIGURE 1. These large sequoias in the foreground as well as the several pines in the background are organisms. The pines are from fifty to one hundred years old while the sequoias are not less than five thousand. When Columbus discovered America these great trees were taller by far than the pines and even towered above the ordinary forest when Socrates was propounding his famous saying, KNOW THYSELF! Published by the courtesy of the United States National Museum.

MAN,—THE ANIMAL

BY

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DEDICATED

TO THE MEMORY OF

HAROLD STEPHEN SMALLWOOD

AND THE SIXTEEN HAPPY YEARS

THAT HE SPENT WITH US

ACKNOWLEDGMENT

The writer expresses his indebtedness to those whose contributions have made the following generalizations possible. It is impracticable to cite each one in the text of such a book as *this*, but it should be clearly recognized that an enormous amount of research had to precede such conclusions as these stated in this work.

The writer also wishes it to be kept in mind that he appreciates that there are many other important aspects of man, especially his religious experiences, but these include fields that others have repeatedly discussed. No attempt is made to deduce the philosophical conclusions that naturally follow from biological generalizations, because this is a phase of the question that belongs to one trained in philosophy.

A more interesting account of the relationships of biology to man could be written if one were willing to select only the more compelling and dramatic aspects of that relationship, but such a description would be incomplete and but partially

true. Life is not understood by any such partial weighing of the evidence. It partakes of the drab and commonplace as well as of the interesting and dramatic.

W. M. S.

May 1, 1921.

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INTRODUCTORY CHAPTER

MAN,—THE ANIMAL

THERE has probably been no time since the Greeks philosophized concerning man, when there have been as many remedial measures proposed for his welfare as now. These measures run the gantlet from the absurd "short courses" in Americanization promising to make citizens in a few weeks to the grotesque ouija board "communications" from the spirit world. Certain sorts of remedies for economic and human betterment are as numerous as patent medicines and about as efficacious. It would seem as if almost any novel or strange or different idea when once found on the printed page forms the nucleus for a cult or school.

It is not the writer's thought to discredit thinking and discussion but rather to furnish some guide-posts to those who would travel out into that unknown which ever lures on the human mind. The unknown is a variously defined country,

depending on the mental traveling outfit of him who journeys forth. For the scholar there are familiar landmarks which keep him from losing his way. These consist in the recognition of facts which he himself or others have verified, and from which he deducts logical conclusions. To the untrained mind the journey is more like a holiday excursion when a new place is visited. Streets, business and buildings afford new revelations and all alike are interesting and suggestive. He does not understand the relative importance of what he sees and like a child each new interest is pictured in glowing terms. Such is a charitable explanation of the numerous fads and fancies that occupy much of our thinking about the life of man to-day.

Ever since man began to ponder on the source and significance of life, the subject has been one of supreme interest to him. Each decade sees some mystery solved which enables us to comprehend more clearly the events and forces that shape life. But for the most part these discoveries are safely tucked away in scientific monographs which but few read because they are couched in language too technical for the general reader. Those minds that are ever aiming to extend the limits of knowledge are too much interested in their researches to pause long enough to translate their results into popular form and indicate their bearing upon

other aspects of learning. So it comes about that frequent popular summaries are necessary, particularly in such basic sciences as physics, chemistry and biology.

The subject of this book, Man,—The Animal, aims to summarize the discoveries of scholars during recent years and to indicate some of their relations to the more fundamental problems of man's physical existence,—problems that many are losing sight of in their hasty attempts to produce immediate changes.

It is not an easy task to draw a sharp line between the physical activities of man and those higher expressions of his mind which distinguish him from all other forms of life. If we include some phases of man's activities which the reader would omit, let us not quarrel over the classification but sympathetically approach our theme in the hope that we may gain a deeper insight into those characteristics which man has in common with all life and which exercise a profound influence on his entire existence.

It is frequently urged that biology is so indefinite that it can hardly be called a science [1] like physics and chemistry; but this attitude fails to

[1] Science consists of a body of well ascertained and verified facts and laws of Nature clearly to be distinguished from the mass of theories, hypotheses, and opinions which are of value in the progress of science.
Osborn, "Origin and Evolution of Life."

take into consideration: 1, that living protoplasm is so complex that it has not been accurately analyzed to date; 2, that there is no other form of matter which is as complex as living protoplasm; and 3, that no exact method has been devised for studying that which we know as the life of protoplasm. These facts compel biologists to write in a more general manner than the chemist, but even he, the chemist, finds it impossible to be specific all of the time. Notwithstanding the complexity and difficulty of the problem, we can say that there is a science of biology which biologists, themselves, regard as well established, with its own methods and technical language. During the growth of the science of biology for the past hundred years, and we should keep in mind that biology is one of the younger sciences, a number of generalizations or fundamental laws have come to be accepted by all students of life. These we shall try to state and to indicate their bearing upon man.

The mere fact that certain given events can be formulated into a law places definite restrictions around their relation to one another. We say, for example, that Halley's comet will complete its orbit in 75 years, which fact expresses a law about the way this comet moves. In a similar way we are able to state certain laws about the life common to all living things; and as we do this, definite

limitations become evident as to what life can and cannot do.

Great importance is attached to a law governing natural phenomena and it is always given first consideration in our thinking. Only a few of Nature's laws have been revealed to man,—more will be discovered with the progress of time. It is, therefore, important that we appreciate how these laws are discovered. First of all we must emphasize that they are not something that man has created or produced. They have always been in existence so far as we can determine, i.e., the laws of life have been true ever since life began; secondly, that their final formulation is the result of many different minds studying the problem. Often the statement of these laws has some man's name connected with it because he had the kind of insight which enabled him to phrase correctly the relations of facts already known. In biology we have the Cell theory of Schleiden and Schwann or Virchow's formula "omnis cellula e cellula," both of which are now regarded as biological laws. These and similar phrasing of the conditions in living protoplasm were not regarded as laws of life until long after their first publication. Many independent observers studying the phenomena of life had to verify all such statements until a large mass of data was accumulated, all of which verified the preliminary hypothesis. If no exceptions

were discovered with the progress of research, eventually, by common approval, the statements were raised to the rank of laws of life. At the end of this long testing, it is easily understood why such laws are regarded as the foundations of our uncertain superstructure of the theories concerning man.

In gaining the facts which constitute the basis for the generalizations of life, biology has not worked apart from other sciences. The physics of optics as applied to the perfecting of lenses in microscopes has been of indispensable value in furthering an accurate knowledge of minute structural conditions in protoplasm. While the application of chemical methods to certain phases of vital phenomena has cast a flood of light on the obscure relations of heat and energy in living things, it is probably correct to say that biochemistry has done more to advance our knowledge of nutrition, respiration and body heat in the past fifteen years than in the preceding fifty years. These discoveries enable one to write with much more definiteness than ever before. We thus come to realize that the generalizations about life depend not only on the work of many persons but also upon the best that the related sciences have to offer.

We would not have you think for a moment that all of the problems connected with the funda-

mental analysis of protoplasm have been solved—many remain as obscure as when man first recognized their existence. With all of the progress of science, we are unable to state how life began. True, there are hypotheses about this important question but not one of them has been proved. The biologist starts with life as it now exists just as the physicist starts with energy and the chemist with atoms and molecules in all of their infinite complexity. They do not try to explain energy, and oxygen or carbon but rather try to discover how these inanimate substances act under varied conditions, and when this has been fully done help man to anticipate and take advantage of these natural laws. As we recognize more of the laws of life and make them a part of our everyday existence, our progress is more certain, and our efforts are more likely to meet success.

One more illustration concerning a second type of problem that still remains unexplained will enable the reader to eliminate this and similar problems from consideration until man discovers some way of solving them. Palæontological studies, in the caves of Spain and France in particular, have revealed that there were distinct races of men that once inhabited these regions long before historic man was known to exist. Here are found the remains of such races as the Grimaldi, Pro-Magnon and Brünn with which we are gradually becoming

familiar—but none of these eight extinct races is definitely known to have been the immediate progenitor of modern man. In all of these investigations, the great majority of opinion is clearly in favor of regarding these various fossils as distinctively human. There do not appear to be any clear transition types between primitive man and the higher mammals though we are led to believe that there must have been since man appeared on the earth after other forms of life became established and since he has more that is common with the animals than is different from them.

This is the type of problem that has perplexed the layman most often. It is the one that we are asked most frequently to explain. Possibly an illustration or two will make it clear that the conditions which surrounded fossil and recent man were not limited to man. Again we take our main facts from the biologist's intimate friend, the palæontologist. He has given a great deal of time to the question of the origin of the horse. Much is known of its history and the gradual loss of all but one toe which became greatly lengthened and constitutes the main part of the leg in modern horses. But our interest should be fixed on that period in the evolution of the horse when there were a large number of species that roamed the mid-western prairies of North America. No less

than a dozen fossil species are known to science but not one of them is accepted as the ancestor of our modern horse. All of these fossil species are easily recognized as horses and we have identically the same kind of problem that was just described for man.

We need not take all of our illustrations from extinct life, for the same principle is illustrated in the numerous domesticated animals and plants. It is probable that man started the present numerous varieties of domestic fowls from the wild jungle fowl of India. To-day by careful breeding experiments, he has more than 100 distinct varieties but all are unquestionably fowls. The same is true of horses, sheep, wheat, oats, etc. Man may be able to control the mating in such a way as to produce a given variety but not in such a way as to produce or create a new genus.

This seems to mean that the more than hundreds of thousands of genera of animals and plants known to science became fixed before man thought of seriously questioning their origin. The result is that the life of to-day is highly specialized and carefully adapted to a given kind of environment. This gives us a non-plastic series of forms to deal with, and science has thus far been utterly unable to reconstruct the conditions under which former changes must have taken place. Some of us feel that such problems as these must

wait until man has made much greater progress in developing methods of studying protoplasm.

We may, therefore, say that the problem of the origin of life and the problems centering around the origin and transformation of genera are not distinctively human questions but that they belong to all forms of life. All that we can do about these and similar problems in the present state of our knowledge is to speculate concerning them. This is a method of discussion which really eliminates them from a purely scientific treatise. For this reason we shall omit all further reference to them as any scientific treatise must do until as a result of extended experimentation and analysis they are solved.

While we all regret that some of the most interesting problems of protoplasm remain unsolved, yet this does not prevent us from taking advantage of the great generalizations that have been discovered. Our first observation is that none of these basic laws of life is limited to man; and our second is, that none of them excludes man. There can be but one conclusion: our understanding of them is indispensable, if we would understand man.

Our first task, then, will be to phrase the laws of living protoplasm; then we shall examine these laws in some detail and indicate their significance as the basis for man's education. Our conception

of education is the learning of facts and relations that best enable man to live in harmony with his environment. For man's environment consists not only of the physical universe together with the animals and plants but also the numerous problems arising from man's relation to man.

CHAPTER II

THE LAWS OF LIVING PROTOPLASM

IT is expected that the reader will accept the interpretation of the word "law" as defined on page 3 and try not to think of these laws of protoplasm in a legal sense although there is much that is identical. The laws of protoplasm and of jurisprudence are both the product of human thinking, but there is this important distinction: Protoplasmic laws generalize the whole of human knowledge in biology and express what man has discovered about living things; while legal laws represent the attitude of the human mind toward human relations, and this is something which is constantly changing.

Some will protest that the amount of our information and the youthfulness of our science makes it impossible to state the conclusions of research in the form of laws. There is much to be said for this conservative view, but it is the writer's conviction that sufficient is known to permit such a statement, particularly in relation to man. The science of biology has progressed to that state where it is able to contribute in a fun-

damental fashion to our insight into a very important feature of man—his animal structures and processes. As we come to analyze these laws in more detail in later chapters, we may conclude that man is much more of an animal than we had supposed.

1. Biogenesis or Abiogenesis.—The first law of life deals with the production of a new individual. Two views have been held. The earlier one dominated human thinking for many centuries and has but recently been overthrown. The later view has had an even greater influence on our conceptions of man in his relation to other living things and is the real reason for genetic psychology.

The view that life could come into being without the influences of preëxisting life or from inorganic matter was held for some twenty centuries beginning with Aristotle, 325 B.C., to Tyndall, 1876. For the ancients there was no difficulty in explaining the occurrence of new animals as complex as insects or even fish. The grotesque extremes to which this easy way of accounting for living things was carried is illustrated by both Virgil and Ovid, who described bees swarming forth from the putrid bowels of the recently killed steer. Frogs, toads, rats and fish were easily conjured from the mud of ponds and streams by the vivifying action of the heat of the sun. Among children and ignorant persons there still lingers a

belief that a horse hair placed in water may become a living worm, as well as other similar crude notions about the origin of living things. This idea that life could come from non-living matter was first successfully questioned by Redi, 1680, who proved that maggots would not grow in meat if the flies were prevented from laying their eggs on the meat. Huxley says of Redi, "The extreme simplicity of his experiments, and the clearness of his arguments, gained for his views and for their consequences almost universal acceptance."

Seven years after the experiments of Redi, microscopic animals and plants were discovered and the theory of spontaneous generation took on a new lease of life, as it was used now as explanation for these minute forms of life. The Italian, Spallanzani, 1777, the Frenchman, Pasteur, 1864, and the Englishman, Tyndall, 1876, are the three great men who successfully devised experiments that conclusively demonstrated that microörganisms did not arise spontaneously.

From the time that Tyndall published his studies until to-day, there has been a very general agreement among biologists that living things arise from some form of existing life and not from inanimate nature from time to time as the ancients believed. The critical observations of the past forty years have conclusively sustained this gen-

eralization so that the first law to be accepted is what is included in the term *biogenesis* (1) *the law that all life is generated from living beings only.*

Chemical Composition of Living Matter.—When life is studied from the chemical point of view the results tell us what chemical bodies are present. No one has been able to write the chemical formula for living matter, and after all these years but little is known of the chemistry of living matter. One of the reasons for this lack of chemical knowledge is that as soon as a chemical analysis is applied to living protoplasm, it becomes dead. So far as our information goes, it indicates that chemical processes are uniform. However, the very great complexity of chemical reactions in living protoplasm makes it impossible at this stage of our knowledge of the chemistry of living protoplasm to do more than state some of the simpler reactions, see page 41, and to indicate what chemical elements occur in protoplasm.

There are some eighty-two different chemical elements known to science and not more than twenty-nine of these ever occur in living protoplasm. Twelve of these are but rarely found, while four are of frequent occurrence. The remaining thirteen are invariably found and believed to be essential to life. These are hydrogen, carbon, oxygen, nitrogen, phosphorus, sulphur,

potassium, magnesium, calcium, iron, sodium, chlorine, and silicon. These elements are the most numerous in the rocks, water and atmosphere. But the amount of these elements, even those that are essential to life, found in an organism bears no relation to their abundance in nature.

Nature has taken just these few chemical units and constructed the endless variety found in living things. This fact alone is one to cause us to marvel that man in all of his complexity, adaptations and differences can be resolved into this limited number of chemical atoms. All that man does is limited to using just these several atoms combined now into this pattern, now into that and beyond certain combinations he cannot go because he is limited by his chemical constitution.

Another law thus specifies what inanimate materials unite to form protoplasm. When a biologist refers to this law he usually expresses it as (2), *law of the chemical composition of living things,* and gives to it the meaning stated under this caption. This law began to be recognized about 1828 with the researches of Wohler, Kolbe, Serthelot and especially Liebig, who first attempted a systematic survey of the chemical processes in living organisms.

All of these several chemical bodies do not exhibit living characteristics except when constituting a part of living protoplasm. We need to keep

constantly in mind Lord Kelvin's generalizations of some fifty years ago, "Dead matter cannot become living without coming under the influence of matter previously living."

Closely associated with the chemical properties of protoplasm are its physical properties which are obvious to even a casual student. But there still remains so much to be discovered in regard to the physical nature of living substance that we are not justified in regarding the conclusions as entitled to rank as a law, so they must be stated as theories.

The Physical Properties of Protoplasm.—When protoplasm is studied by means of the microscope, it presents a certain appearance. This varies with the kind of protoplasm being studied and whether it is alive or has been fixed by such chemical agents as picric acid, formalin, etc. Up to the present it has been impossible to give a single, physical description of protoplasm that applies to plant and animal, muscle and nerve, or egg and gland cell protoplasm. The physical picture presented by protoplasm under different conditions of activity and in different organisms has been accounted for by the two following theories, neither of which is entitled to be ranked as a law.

a. Fibrillar Theory.—The adherents to this theory claim that a distinct meshwork of cytoplasmic fibrils can be made out when suitable treatment is employed and such terms as

spongioplasm, reticulum, filar substances, etc., are used to describe the meshwork. Filling in the meshes there is a structureless sap-like substance. For some cells and for certain phases of cell activity the fibrillar theory adequately describes the structural conditions of the protoplasm.

b. The Alveolar Theory of Butschli.—This theory assumes that protoplasm consists of two fluids, one suspended in the other. The fluid that is suspended is made up of numerous minute drops which give the appearance of closed chambers or alveoli. The containing fluid is continuous and occurs between these minute alveoli. By mixing rancid oil with sodium carbonate a solution is produced that imitates very closely the appearance of protoplasm.

3. The Law Governing the Relation of Life to the Living Body—is that life does not reside in any one structure in the body of plants, animal or man but is present in all of the parts. It cannot be measured, photographed or weighed. Even a child can tell a dead animal from a live one, but no one can isolate that which makes an organic being living. This general diffused, immaterial condition, life, may be driven from the organism by a multitude of causes and leave all of the parts intact as when life was present—in some instances the several parts may remain alive for hours or days after life has departed. This is well illus-

trated by taking the heart of a frog from the recently chloroformed animal and placing it in salt water. The heart now begins to beat in a rhythmic fashion. Living cells can be taken from various animals and when placed in an artificial culture can be kept alive for months at a time. In one instance connective-tissue cells, isolated from the heart of a chick embryo, have been kept alive for seven years. Under such conditions they are entirely separated from the living animal; and, while able to grow under this abnormal condition, they cannot give rise to a new individual like the animal from which they were taken. The influence that life thus has on the material substance which composes the body of living things is important. When changes occur in non-living material disintegration and simplification usually follow; while the living organisms possess something that is absent from the non-living. A general term is used to express what appears to happen, although it does not clearly define the process. This term is adaptation. When some disturbance acts upon the structure or internal vital conditions, the living body adapts itself. There is a readjustment, so that the wound heals or the poisons from a given disease are overcome. After one of these readjustments, we have the same recognizable organism. The living body can maintain itself under a wide range of external conditions and undergo

a variety of mutilations and still retain its life, thus constantly having a changing normal, due to the influence of its living condition.

4. The Law Governing the Size of Living Bodies.—The size and shape of living bodies cannot be stated in any general expression. Some are so small that the highest power of the microscope has failed to reveal them, while the giant redwood trees tower above all other living things by many feet (Fig. 1). Between these two extremes are found a multitude of sizes each of which is characteristic of a given species. Animals have never grown to such large size as some of the trees, although some of the fossil forms were nearly one hundred feet long (Fig. 2). When a given kind of plant or animal comes to have a certain size and shape, there are only minor variations from year to year, as both appear to have become fixed for a given species and are continued from generation to generation by heredity. The law regulating the size of living things is most variable and yet definite limits are known to exist. These limits are intimately related to the conditions set forth in the 9th law.

5. The Law Governing the Age of Living Bodies.—A number of the unicellular organisms retain their individuality for not more than thirty minutes under normal feeding conditions (Fig. 3); while the great redwood trees have retained their

FIGURE 2. Photomicrograph of the plant Bacillus tuberculosis, an organism that keeps its individuality under ordinary growing conditions for about thirty minutes. Owing to the habit of this organism of living as a parasite within the body of man, the average annual number of deaths in the entire state of New York is 15,805; in the United States annually 101,417; and an estimated number of between two and two and a half million deaths annually in the entire world. Photograph by Henry N. Jones. Figures by Dr. Otto R. Eichel, Director of the division of vital statistics for New York State.

individuality for possibly twenty centuries, and between these two extremes are to be found all gradations. It is customary to speak of the longevity of a group of plants in such terms as annuals or perennials, which means that certain species have come to have a certain fixed period during which they live. One of the real problems in biology is to explain old age. It is now conceded that this is a natural stage in the life of all organisms; but why should one come to have the ability to live for centuries and a closely related form but a hundred years? All organisms pass through three stages, youth, maturity and old age, which are intimately associated with organic maintenance, but even when the body is supplied with suitable food, it grows old. There is a law governing the age of every living thing known to science, for no organism has been proved to be immortal. Only a few of the factors governing the length of life of any given form of life are known.

6. The Law of Structure, the Biological Unit.—Men had been describing animals and plants for more than 2000 years before any general statement that was to stand the test of careful study was formulated as to their structure. In 1838, two Germans, Schleiden and Schwann, reported that they were unable to find any plant or animal that did not contain at least one cell. This tech-

nical term has been used for nearly 200 years, but it remained for these two men to formulate the generalization that was to place the study of Biology upon a scientific basis. All life begins as a single cell and the cell is the smallest vital unit into which a complex living body can be resolved. The trees, the daisy, the bird or man can be analyzed in terms of the cells found in each. This word, cell, is the name for the active, vital substance, protoplasm. This means that such questions as disease, heredity, growth, old age, in short, every biological question, can only be answered through a study of cells. The cell, then, is the modern starting point for all biological problems. The law of structure for all living things asserts that they are composed of one or more than one cell.

7. *The Law of Growth.*—We can distinguish in living things a number of common parts, for example, all fish, frogs, and men have a heart, stomach, kidneys, a nervous system, skeleton, muscles, etc. Perhaps you have noticed the gradual growth from infancy to maturity of an individual in one of these great groups of animals. The most searching inquiry fails to find any new parts added but rather a turning of the immature structure into a mature state. This is easily illustrated by examining the wrist of a child and comparing it with that of an adult. How do the adult

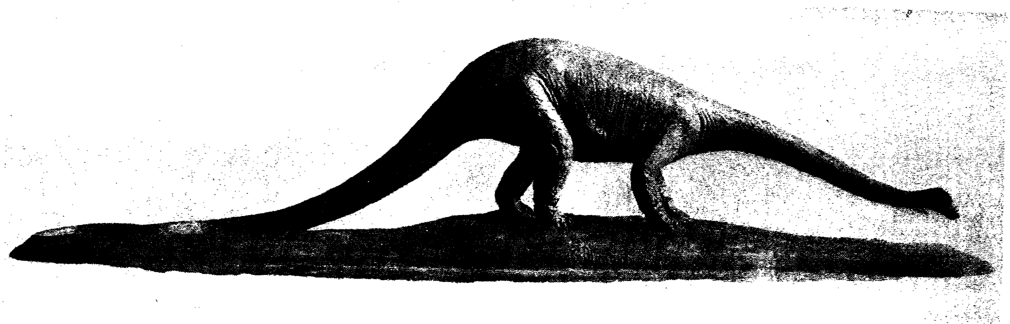

FIGURE 3. A restoration of the herbivorous dinosaur, Diplodocus carnegii Hatcher. Probably the largest animal organism known. This remarkable monster was eighty-seven feet long and, although it lived thousands of years before the existence of man, we can confidently predicate that it exhibited all of the living characteristics of a modern animal. Restoration made by C. W. Gilmore and is published by the courtesy of the United States National Museum.

bones come into existence? The cartilage grows until it becomes bone. These changes are numerous and known in minute detail. But the bone is a different material and it must have come from somewhere. The answer to this query leads to a still more fundamental question, namely, the distinction between living, organic growth and non-living, inorganic growth.

Hills, valleys, sand-bars and crystals are all said to grow. It is well to compare the growth of a crystal with the growth of protoplasm. 1, crystals grow only in a highly saturated solution of material like the crystal itself; while living things can grow in a weak nutritive solution; 2, this nutritive solution does not contain the chemical compounds found in the living cell, while in the case of the crystal, the substance of the crystal and its nutritive solution must be chemically identical; 3, growth in living things leads to the reproduction of more living things, while growth in inorganic nature never does. LeConte tells the significance of organic growth in the following condensed sentence, which we may designate "The Law of Growth": *"Organic life manufactures materials like itself out of materials wholly different from itself, and then uses the product for growth."*

Aristotle directed attention to this problem of growth, but it was not definitely formulated until Wolff, in 1774, published his studies in Embry-

ology, growth changes and the accompanying differentiation of structure on the immediate result of unequal division in the biological unit. Little is to be gained by trying to use the terms development, growth, and differentiation, with a specific meaning, for none of them aims to do more than describe what happens after unequal division in cells has taken place in the embryo and until the adult form is reached.

8. The Law of Sensation (Sensitivity or Irritability).—This is a phase of organic beings by which they become aware of their environment or make some change in their behavior because of it. The general term describes several distinct processes, such as the power to appreciate an appropriate stimulus, to conduct the stimulus to a recording center or centers, and to transform the stimulus so that movement results. Just how many distinct processes are involved in this most elusive of all vital phenomena, we do not know. We are unable to explain how the stimulus travels in protoplasm, nor just what transforms the stimulus so that a definite movement takes place. In higher animals sense organs and a highly developed nervous system enable them to gain accurate information concerning their surroundings, and for man as well as for these higher animals this is the sole avenue of information concerning material substances. Through this property come all of the

numerous adaptations of organisms. *The Law of Sensation includes the reactions of living protoplasm to external stimuli.* "Any external *condition which modifies the activities of a living organism may be called a stimulus.*" There are positive stimuli, such as light and sound, and negative, such as darkness and silence.

9. *The Law of Maintenance of Life (Metabolism).*—Not all of the young plants and animals grow to maturity nor do all adults continue to live to old age. Death is one of the most obvious facts connected with life, and it occurs at all ages. The keeping of the living body alive is a process distinct from growth, for it continues long after growth ceases.

All biologists, physiologists and pathologists use a rather exact and technical term to describe this general condition which is true for all periods of life, from the embryonic stage through youth to maturity and old age. The term is Metabolism. *The Law of Metabolism, includes the chemical changes that take place in food after it has been eaten, the changes while it is being built up into living protoplasm, and the changes through which it passes in finally furnishing energy to the living machine, or in being cast off as waste.* These several changes are engaging some of the best scientific minds of our day, among both chemists and biologists, and yet much remains unknown. We

can trace food nearly up to the living condition but not entirely. It is easy to note the wastes of vital activity, but no one knows just how the vital energy is produced. All understand that vital energy is sustained by furnishing the proper amount of food. When this is lacking, the living body begins to eat itself, as is shown by starvation, but "when death from starvation at length comes, the old flag—the flag of life—is still flying."

We know something of the chemical agents that accelerate the digestive changes in food. We do not know quite as much about the chemical bodies (technically called enzymes), that render the digested food still more complex, until it approximates the complexity of protoplasm. We know practically nothing of the agents that cause living protoplasm to give off wastes. These several processes, embodied under the Law of Metabolism, serve to mark off sharply the activities of living things from all forms of activity in non-living matter.

10. The Law Governing the Fate of Dead Bodies.—Ultimately all forms of life die, and yet the surface of the earth is not cumbered with them as it must have been had they retained their living shape and size after death. An orderly series of changes occurs which breaks down the chemical bodies in dead organisms and the material substance of the dead amœba or man is re-

turned to nature. No exceptions are known to this law—no organism is exempt from this ultimate fate. We may thus say that this law deals with the orderly series of changes, discussed on page 25, which takes the material substance of organisms and returns it to the non-living, uncombined state. Possibly the most conclusive evidence that these generalizations are actually laws of living protoplasm is the fact that none of them can be reversed by man, as is the case with the laws governing changes in non-living matter.

These ten laws of protoplasm rule supreme in man. They express the scope and limitations of his organic activities. He can not set one of them aside. He would not be a man were one of them lacking. Every new human being must conform to them just as every human being has had to conform to them in the past.

In the following chapters we shall discuss several of these laws in more detail and indicate their relation to man's education.

CHAPTER III

THE BIOLOGICAL UNIT

CIVILIZED man devotes much of his energy to classifications even if they have to be supplanted by other classifications on the morrow. So numerous are the units upon which groupings can be made that experts are required to explain them, for example, a given number of unit movements in laying bricks or nailing on laths. This unit idea came from science where it is the common practice to start with what appears to be an indivisible unit, such as ohm, watt, kilogram, atom, ion, and numerous others. He who would read of efficiency methods or know about electricity, chemistry or any present-day treatment of such themes, expects to master first the units on which the whole plan is based.

We are so accustomed to regard man himself as a unit that it seems odd to think of him as containing literally millions of biological units, all working in harmony, all contributing to his life as a whole. It was a long time before man was placed in the same category as other living things in this respect. It seems perfectly harmless to describe

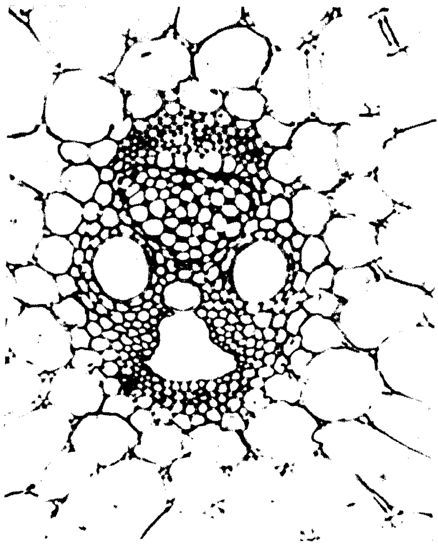

FIGURE 5. A portion of the common corn stem. Note that the difference in shape and size of the cells produces marked differences in appearance. Photograph from the collection of the New York State College of Forestry.

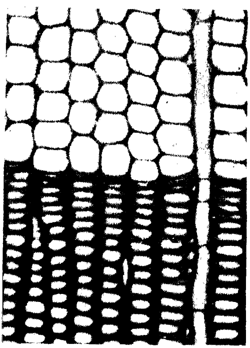

FIGURE 6. Is a portion of the trunk of the tree known as sequoia sempirvirens. The larger, open cells grew in the spring, while the smaller and denser cells formed during the summer. Photograph by Professor

FIGURE 7. Photomicrograph of the red blood cells of the fish Amia calva. Each blood corpuscle remains free to move about and thus do not unite to form tissues as in Figures 5, 6, 7, 8 and 9.

the cells of plants and animals, but the bitterest denunciation was showered on the heads of those who first stated that they were able to find cells in the body of man, for this conclusion implied that there was a scientific similarity between man and animals. If the researches had revealed that there was a different unit for man, then it is doubtful if any common relationship could have been established.

If we are to understand man, the animal, we must become familiar with the biological unit, as the electrician is with the watt or the chemist with the atom.

It was an English investigator in 1665 (Robert Hooke) who first suggested the term cell to describe the small cavities found in a thin section of cork. The word as thus applied referred to an empty space with a definite wall described as "little boxes of cells distinct from one another," but there is no living substance in cork such as Hooke examined. All that was present was the empty shell.

More than 150 years passed by before the scattered observations of many students were corelated, and it was recognized that there is a constant structure in plants and animals. The long delay in arriving at this simple generalization was largely due (1) to the lack of appliances, such as the microscope; and (2) to the fact that the attention

of students was centered on the larger organisms. It was not until men saw that they could not explain the work of an animal in the terms of its organs that they began to delve deeper.

As soon as scientists recognized that all life was built upon a plan and that definite units, the cells, constituted the structural frame-work, a long step in advance was made. Here was furnished a starting point for all subsequent study.

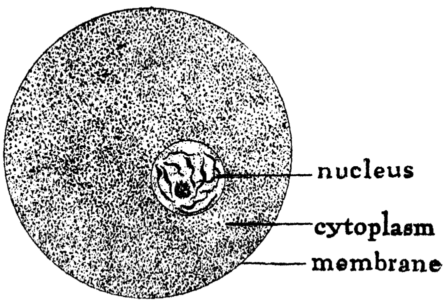

FIGURE 4. Partly diagrammatic sketch of a star-fish egg. In shape and in relation of the various parts, this represents a typical cell.

From 1850 on to the present day, the progress of our information on this aspect of life has been rapid. Since this date we have come to realize that the term cell, as originally applied, was a misnomer. The vital part of the cell is what occurs within the "little boxes." To this living substance is given the name protoplasm. It nearly always consists of two easily recognized parts:

(1) a central, sac-like body, the nucleus; and (2) the larger mass surrounding the nucleus, the cytoplasm (Fig. 4).

The number of cells in an animal or a plant is no measure of their relative rank in the scale of life, as the following examples indicate: The extinct mastodon contained thousands more cells than man; the huge Californian redwood trees have more cells than any other living thing, yet they differ only in size, not in function, from our common trees. These facts are made more significant as one studies the varied appearances of cells as shown in figures 5-11. It is not the number of cells in an organism that determines its rank, but the quality of the vital processes that take place within them.

It is instructive to reflect on the relations of the multitude of cells in the body of man. Are there any classes? Are all equal in importance? Are there some which grow weary and old with service and must forever hide under the organization of the larger unit of man?

In so far as the higher animals are considered, man is conceded to be the most specialized and highly organized of all. The biological unit in man is differentiated into such tissues as muscles, glands, bones, skin, nerves and blood. Bone cells consist of enormously thickened cell walls with the vital, living protoplasm reduced to a minimum.

Such cells are devoted to support and protection. In order to do this service well, they have lost through disuse their power to contract or to respond to a stimulus. These cells stand in striking contrast to the blood cells that float in the plasma-fluid as isolated units. Each red blood corpuscle transports oxygen from the lungs to the other cells that are fixed in their location in the body, and carries carbon dioxide, a waste from these same cells to the lungs. They constitute the internal transportation system; they always travel the same route and always carry the same load until exhausted, when they are caught in the spleen, the cemetery for red blood corpuscles. Blood and bone cells offer interesting contrast between closely related cells, as both belong to the same tissue system, the connective tissue: cells that are more closely related than are tinners and plumbers in our social system.

The relations between this unit in muscles and nerves is equally illuminating. The cell which is specialized into a muscle cell has undergone a high degree of development in that it contains specific structures associated with the work of contraction. As these cells work, their action is limited to a single change—shortening their length and returning to their normal linear shape. This they do every time they work and there is no change or

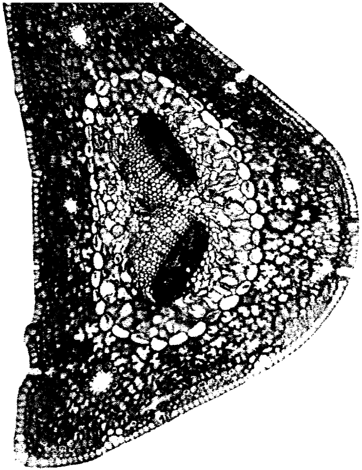

FIGURE 8. Photomicrograph of section of pine leaf (needle). The different shapes and sizes of the cells enable one to easily recognize the thick epidermal layer on the outside. Centrally located, surrounded by a bundle sheath which looks like a string of beads, are the cells which conduct materials through the leaf. The dark mass of cells carries food material. Made by Miss Winifred Dixon of the Botany Department, Syracuse University.

FIGURE 9. Photomicrograph of the spinal ganglion of the turtle. Notice the typical cells with nucleus and nucleolus. The black area with light centers are sections of nerve fibers. Preparation by Miss Lucy Watt of the Department of Zoology, Syracuse University.

promotion. Nerve cells in contrast have become attenuated into minute fibers connecting distant structures. These fibers are specialized to conduct stimuli from one part of the body to another. This they must ever do. But in some manner, not wholly understood, they have a regulatory and controlling action on all of the remaining cells of the body of man. It is no stretch of the imagination to designate them as the ruling class. For it is common experience that the injured nerve results in blindness or paralysis. The nerve cells have a large responsibility in keeping all of the other cells working in harmony, for man's well-being, as they transmit the proper message to gland and muscle at the correct moment. The success of those animals which do their work best justifies us in attaching great importance to their rule. For as we descend the scale of organization and find cells acting independently, we shall see that they are not as expert and therefore not as successful as in man.

There is nothing that approaches sovietism in the distribution and work of the biological unit in the body of man. The opposite is rather the case, for our unit is arranged into classes, where one must serve as "hewer of thy wood and drawer of thy water," while another takes the rank of the king. This dominance of certain cells and sub-

servience of others is one of the important facts that we have to consider in this form of analysis of the body of man.

The second general condition governing the relations of this unit in man is that we cannot subtract any one class of cells and retain the life of the whole structure. Organization has gone so far in man and all of the higher forms of life, that a given group of cells is unable to take up the work of any of the other groups. If both kidneys are destroyed, excretion cannot be carried on; or if the lungs become tubercular, respiration is hindered and finally prevented; we never learn to hear or see in the case of permanent blindness.

The interesting experiment in "cultivation" of the biological unit outside of the body in a living

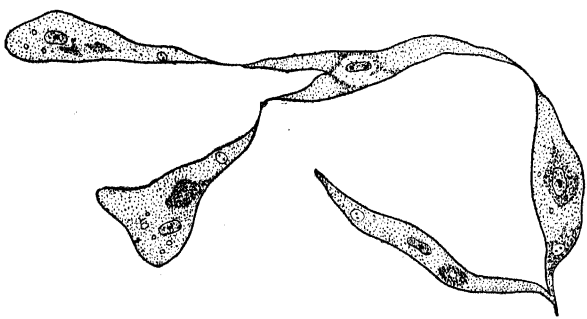

FIGURE 12. Series of single heart-muscle cells which have been observed to grow, beat separately, unite with one another and finally beat in unison. Redrawn from Tower and Herm. Am. Mus. Jour., 1916, xvi, 473.

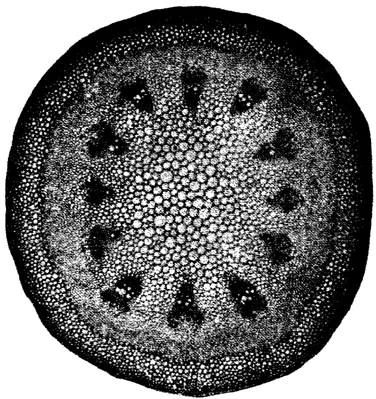

FIGURE 10. Photomicrograph of section of young stem of Aristolochia, a climbing vine. The cells have begun to form special regions such as the twelve conducting bundles. Compare with Figure 11. This young stem is about the size of the lead in a lead pencil.

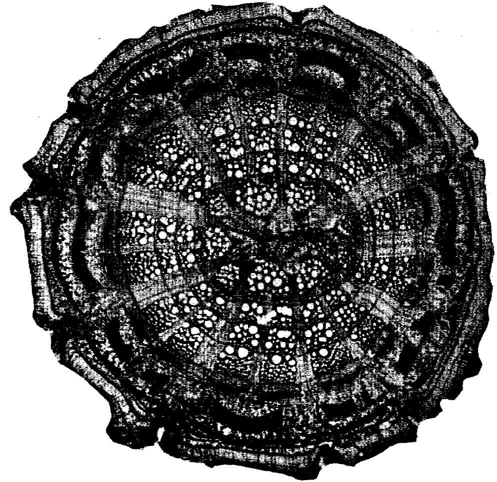

FIGURE 11. Photomicrograph of section of mature stem of Aristolochia. This stem is four years old as shown by the rings of growth. The radial fibers are termed wood rays and have formed between the conducting bundles as shown in Figure 10. This mature stem is about the size of a lead pencil. Preparations by Miss Ethel Eltinge of the Botany Department, Syracuse University.

condition has given us a different notion about the relation of the life of the cells in the body as a whole. Ever since Harrison showed how living cells could be kept apart from the body of the frog tadpole, and that they would develop normally when immersed in coagulated lymph, we have been wondering what is the distinction between the life of cells and the life of the whole organism.

Carrel isolated some fragments of connective tissue in 1912 which were still active in 1920, after more than seven years of life outside of the body, the rate of growth having remained the same after more than a thousand transplantations. Such experiments throw new light on the problem of senility and death. For it is conceivable that the length of life of the biological unit outside of the body greatly exceeds its normal duration when

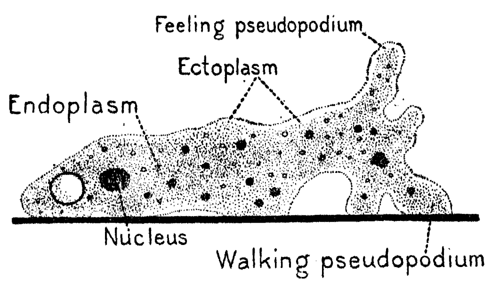

Figure 13. A drawing of an ameba seen from the side. There is no definite cell wall and the pseudopodia can be formed in any direction. There is no mouth but food can be taken into the body at any place.

bound and limited by its organization in man. Our biological unit has to pay some sort of a price because of its association with the higher organization. This important conclusion stands out in strong contrast in the brief description of free living types of cells that follows. (Fig. 13.)

The first illustration of a free living biological unit is taken from one of the microscopic animals because we shall find that it helps us to understand many features in man's activities; while our second example is a still smaller unit but clearly a plant whose work is of such great service to mankind that we could not have lived through the centuries without it.

The ameba (amœba), figures 13, 14, is one of

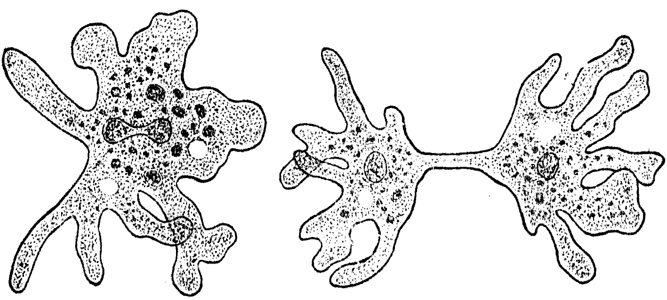

FIGURE 14. Drawing of an ameba to show how the body is cut into two parts in reproduction. The division begins in the nucleus and later extends to the cytoplasm. When the division is complete two new amebas are found where one was before.

the best illustrations of a free living biological unit. The body is irregular in outline with various branches extending from the central mass. Even a superficial glance reveals a nucleus, surrounded by a somewhat homogeneous appearing area which is the cytoplasm.

There is nothing permanent or fixed about the shape of this living cell. The animal moves about by using some of its cytoplasmic extensions (Pseudopodia) as legs to walk on, and some of them as feelers to search for food. There is no mouth nor stomach. The cell does not have to turn around when a morsel of food is found. It simply forces the food particles into the cytoplasm, and moves on in search of more food. We say that the food thus taken up is now digested, but no one claims that he can actually prove this statement by studying the ameba alone. One must reason from analogy. The facts set forth in Chapter II page 15, indicate that chemical processes are similar in all biological units. One can experimentally prove that digestion is necessary in all higher animals and the chemical changes are comparatively well understood. There is no evidence that any plant or animal is able to utilize food without changing it so that the living protoplasm can use it. From these reasons, very sketchily presented, we judge that the ameba must digest the engulfed particles of food.

But the ameba has no stomach with glands nor any special glands to provide a digestive fluid. It must be inferred that the protoplasm of the cell has itself the property of producing digestive fluids. After the engulfed food has been in the body of the ameba for a short time, it can be seen to undergo changes in form. There are some parts that apparently cannot be digested, since these are moved to the surface of the ameba's body and eventually discharged into the water.

When one is studying a number of amebas, he usually finds some of the individuals deeply constricted in the middle, and, if one of these is observed a few minutes, he finds that the constriction deepens until the animal is divided into two equal parts. (Fig. 14.) The result is that two amebas are now found where there was but one. It is impossible to indicate which of the two is parent and which is offspring. The body of the parent has divided into two children but with no parent existing other than as it persists in the bodies of these two children. As the two small amebas grow, they in turn repeat this simple process of reproduction, but there is no outside stimulus that can be applied that will force such a cell to undergo this process. Where does it end? When does old age begin in such unicellular forms of life? Do these forms ever die?

From the time that Weismann announced that

these microörganisms were immortal because they never die, experiments have been made to determine just how long some of them can go on dividing. Professor Woodruff of Yale has been carrying on an experiment during the past ten years. During this time more than 5000 generations of descendants have been recorded from a single animal (paramecium). (Fig. 15.) In this brief period he has been able to review many more generations than would be possible in the

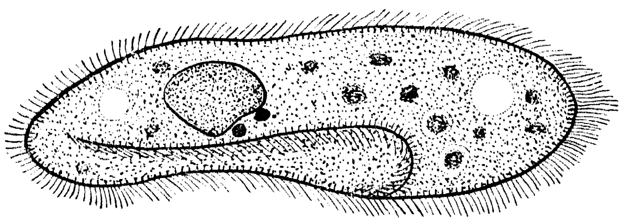

FIGURE 15. This is a drawing of protozoa, Paramecium aurelia, which Professor Woodworth has observed to divide 5000 times in a manner similar to that shown in Figure 12. The surface of the body is covered with minute cilia which are used in locomotion and in securing food. The large mass and the two small black dots are nuclei. Scattered food vacuoles occur in the cytoplasm as well as two excretory vacuoles, shown as clear circles in the figure.

more slowly reproducing forms of life. For such animals as paramecium maintain their individuality for not more than 12 hours at the longest, under normal conditions. Let us compare man with this protozoan. We assume that three generations of men will be produced in each century.

Upon this basis, thirty generations of men would be produced in a thousand years. This study upon paramecium, then, includes more generations by far than the whole of human history.

It would seem from such a study as if some of these animals could go on indefinitely and that they are in a scientific sense immortal. But other studies covering a wide range of unicellular life show in many instances that these animals actually grow old. Physical changes occur in the protoplasm which are similar to the conditions found in old cells in the aged higher animals. Death is a part of the life of protozoa as in the higher animals and seems to have many of the same features. There comes a time when these animals grow sluggish in their swimming habits, when they fail to produce offspring and when they cannot be artificially rejuvenated by a change of food or some stimulant; when this stage is reached, the term old age is used to describe it.

Another aspect of the life of an ameba is one that requires the use of terms usually confined to animals with a definite nervous system. When the ameba creeps about, its streaming protoplasm comes in contact with a wide variety of particles of matter. Some it selects as food; others it passes by in an apparently indifferent fashion; while from another it recoils. Several terms are necessary to describe any one of these reactions.

1. The ameba is able to distinguish between different particles of matter. Each particle must then give to the ameba a different kind or form of stimulus. Such facts are considered under the term irritability or the power to appreciate a stimulus.

2. Such stimuli were obviously conveyed within the periphery of the protoplasm as changes in shape took place in regions separate from the point of the stimulus. This is designated as conductivity or the power to carry or convey a stimulus.

3. The observed facts in connection with the ameba's response to different stimuli show that the protoplasm assumes various positions in relation to the foreign body. In short the protoplasm was made to contract—much as a muscle contracts; and the term contractility, is used to describe such changes.

4. But between the appreciation of the stimulus and the contraction of the body some adjustment has taken place within the protoplasm. For the ameba hungry and the ameba that has just eaten its fill act in an entirely different manner when particles of food are met. There are really no impersonal terms which can be employed to describe these conditions, so we have to use those that usually have a human meaning. In doing this, however, we are simply trying to make clear what

probably happens. We must say, then, that the ameba exercises choice and that it can interpret stimuli. The technical term of coördination is employed in this connection as indicating that the ameba is able to use the information received from the stimuli.

The manner in which living protoplasm responds to external stimuli constitutes one of the most essential distinctions between living and non-living states.

The consideration of these elementary responses in protoplasm suggests the sense organs, nerves, brain and muscles of man. It is true that in an elementary way the ameba can carry on the same kind of response as the man, although there is no structural evidence of nerve, sense organ or muscle.

One is just as much at a loss to understand what happens to the stimulus after it enters our brain through the eye or ear. The many studies that have been and are being made on the ameba and other simple animals are all attempts to understand what really is happening within the protoplasm. Every new fact about any form of life, grasped by the human mind, helps it to explain and understand all life.

This microscopic bit of protoplasm in the body of an ameba is clearly a fluid without any contain-

ing wall. It streams, now in this direction, now in that, but always under the ameba's control. If, by any chance, one presses too heavily upon this delicate organism, the life of the ameba is destroyed and the protoplasm begins to mix freely with the water. In two or three minutes the body of the ameba becomes unrecognizable. One has the same difficulty in trying to describe what was destroyed in the ameba as in man. A beginning student can tell whether an ameba is dead or alive, while the ablest philosopher or scientist cannot tell what the ameba lost when accidently crushed.

The life thus seen to center in a microscopic ameba is similar in all essential details to the life in man: every fundamental fact associated with the biological units in man is present in an ameba. It is true that man does not contain in his body any cell that can carry on as many vital processes as does the ameba, but it is also true that the ameba cannot move as quickly, transmit stimulus as rapidly, nor protect itself as effectively as does man. Generalized ameba is not as efficient as specialized man.

The second type of biological unit existing within the limits of a single cell which we will consider, are bacteria. All bacteria are plants but they are but one of many plants that live in a

single-celled condition, just as the ameba was but a representative of numerous single-celled animals.

Bacteria appear in three general shapes—the straight rod, known as the bacillus (plural bacilli); the bent rod, the spirillum; and the sphere, the coccus or micrococcus. When we remember that there are more than 1500 different kinds of bacteria and that all of these different kinds must come within these different shapes, we see how utterly impossible it is to distinguish the different kinds by shape. (Fig. 2.)

Bacteria used to be spoken of as the smallest living units, but science has revealed a group of living things known as ultra-microscopic, so that bacteria are considered as relatively large. However, they are so small that the high powers of the microscope are required to reveal even their presence. When one speaks of their size and suggests that one hundred of the micrococci might be placed on a single period found at the end of one of the sentences on this page, no accurate form of measurement is presented. When scientific workers tried to measure these minute plants, the millimeter was found to be too large, the divisions of the inch having been found previously to be entirely unsatisfactory. The next problem was to divide the millimeter into thousandth parts, each of which is called a micron or micromillimeter.

Thus a micron is 0.001 of a millimeter or approximately 1/25,000 of an inch. The micron is a unit of measurement that is small enough to be applied to bacteria. We find that the micrococci and the width of bacilli average about 1 micron. The bacteria which cause lockjaw have a width of 0.2 micron and a length of 5.2 microns; while some of the spirilla may have a length of 40 microns.

The distribution of bacteria is universal whereever there is food upon which they can exist. The mere fact that they are found in so many different situations, living equally well in the air, in the upper layers of the soil and in the water, reveals their wide adaptability. It also means that they can live on an equally wide variety of foods.

Many bacteria are able to move about from place to place. Some move slowly while others dart past rapidly. When studied under the microscope, their motion seems very rapid on account of the high magnification. While some of them have been estimated to travel with the speed of an aeroplane, most of them move very much more slowly. If the comparison of the rate of speed of the slower moving bacteria is made with an automobile, the speed would be between 10 and 20 miles an hour.

These minute plants are extremely simple in structure. The cell wall is usually surrounded by a slimy or gelatinous capsule and it is not like the

cell wall of higher plants which is composed of cellulose. Their diminutive size prevents one from learning very much about internal parts. There is no distinct nucleus.

Their method of reproduction is similar to that of the ameba, figure 12. When a bacterium has reached mature size, it begins to form a constriction in the middle of the cell which proceeds until the cell protoplasm is completely divided. The two parts separate and two new bacteria are made. A generation, then, among bacteria is from one division of the cell to the next one. This time is often very short, from twenty to thirty minutes, which makes it possible for the bacteria to multiply very rapidly and is the main explanation of why these microscopic plants are capable of producing such remarkable transformations in nature.

Much study has been given to the feeding habits of bacteria and we have come to appreciate that some live like animals, some have synthetic powers similar to green plants, while others are able to subsist in more primitive forms of energy combinations than either animals or plants.

In their methods of living they reveal no new basic principles but do show some special adaptations that enable them to render man an invaluable service.

The chemical analysis of the biological unit, wherever it exists, yields the same chemical ele-

ments, so that it is evident that all living organisms must draw their supplies from the same source. When these chemical bodies have once become a part of the body of a plant or animal, they are unavailable for any other plant or animal until released. The living organisms thus lock up in their bodies a vast amount of material which is valuable to other forms of life. As long as the organism is alive, it is necessary that this material remain in it, as it constitutes the material substance of its body. But when death ensues, it can play no further part in the life of the organism. This material substance, however, would forever remain inaccessible were it not for the work of these microscopic bacteria. The sparrow or the tree that falls to the ground is immediately preyed upon by numerous animals and plants until a shapeless mass has taken the place of each. In this transition many changes have occurred, the most important of which bacteria and other fungi produce. Their work results in a simplification of the complex bodies which the sparrow and the tree had so carefully and elaborately built up. The simplification continues until the body of each returns to the air and soil from whence it originally came. The body of man forms no exception to this process. "Dust thou art and to dust returnest," while not spoken of the soul is most decidedly the fate of the body. That the dead body

of a mammoth mastodon or of a man should be under the dominion of unicellular plants is one of the most interesting of modern discoveries.

Indeed, this is a fortunate condition. For were it not so, there is a possibility that the present life on earth might exhaust some of the necessary chemicals such as nitrogen, oxygen, hydrogen or carbon which are indispensable to the continuance of life. Before these bacterial relationships were solved, it was a common prediction that life would have to end for the lack of suitable materials of a chemical character. Now we know that this can never occur, for as soon as an organism dies and disintegrates the several chemicals of which the body was composed return to the air and soil and are ready to be used again.

Science has been unable to discover that it makes any difference how long or in what plant or animal these chemicals remain. That the oxygen that we breathe has been a part of the body of some other organism is very probable. But after its varied relations in the protoplasm of animals, plants or men, it now possesses the same chemical properties and can do the same important work in living protoplasm as if it had never been a part of any other organism. It was not until 1893 that these relationships were fully recognized.

In a sense man's body is like a house made up of different kinds of bricks. The bricks that are

used to build a house can also be used to build a factory, a saloon, or a church. In each relation, they serve their part, but the bricks do not constitute the building. The building may be used successively as a church, a clubhouse or a saloon, as the purpose of the owner at the time may dictate. It is the peculiar life of the plant like a rose, the life in a horse or in man that makes the difference, and not in the material out of which each is constructed.

The life of this biological plant unit is as the simple ameba, like the life in the cells in man's body. Even this brief review of their services to other forms of life reveals one of those close relationships that is more important than the differences that exist between man and other forms of life. Man's dependence on the work of bacteria alone justifies the earlier statement that man has more in common with such forms of life than he has, that differs. In this study of the biological unit, one of the fundamental categories of life, a deeper understanding of man's organization is gained. It clearly indicates that man does not exist apart from and distinct from other forms of life.

Science has no answer to the question, why life should be confined within the limits of cells or why all vital phenomena should be carried on in such microscopic compartments. But science has been able to discover that every living thing

consists of one or more cells and concludes that cells are essential to life; and furthermore, science recognizes the important fact that it is within the small compass of the cell that we must seek for further information in regard to the nature of life, whether it be man, animal, or plant.

CHAPTER IV

WHAT MAKES MAN GO

ONE of childhood's earliest questions, suggested by the first mechanical toy, is "What makes it go?" Later the same query is applied to his own body. We are still asking "What makes us go?" Nearly every magazine has a patented food preparation that guarantees to make man go better than do ordinary foods. There is but one method of approaching this problem and that is through a study of the relation of energy to life processes. What are our resources? Under what limitations and regulations do we move?

We do not know when man first noted that heat was produced in living things. Whenever it may have been, there was no satisfactory explanation of this fact until the chemical substance oxygen was discovered. It was the French scientist, Lavoisier, who pointed out that the use of oxygen in respiration resulting in the production of heat, was a chemical process. His suggestion, made in 1792, marks the beginning of our knowledge of what makes the body go.

The body goes because it is furnished with

energy from the food eaten. This simple statement fails to convey anything of the complexity of the problem or the steps in the process that still remain unknown. It is an easy matter to write the word energy, but what do we really mean by it?

Ever since Huxley taught biology in the Royal School of Mines, teachers have been using his illustration as an introduction to this theme. It is the familiar one of the steam and coal.

When coal is burned in the firebox of the engine, heat is given off that transforms the water into steam. This steam is used to move the engine. Smoke, ashes, and some heat are the wastes in this process. Locked up within the coal, there is an amount of energy that can be accurately computed. No mechanical device has yet been constructed that is able to utilize all of this energy. There is always a varying amount of waste.

Here Huxley's comparison must cease, as further analysis reveals that there is no real similarity between an engine and a living animal, not even in the manner in which they utilize energy and do work. The illustration however, helps one to see one aspect of the problem—an aspect that is necessary in a scientific discussion.

The grain and hay fed to a horse are utilized by the horse and there is a noticeable amount of waste. As a result of this feeding, the horse is

able to draw a load. The exact amount of energy in this food given to the horse can be accurately computed and the horse like the engine is unable to utilize all of the energy in its food.

A machine can do no more work than that made possible by the available energy furnished it. The heat produced by the burning coal releases the potential energy stored in the coal for possibly a million years and transforms it into active, kinetic energy. In this change, even though it be distributed to several machines, none of the stored potential energy is lost.

Chemical energy refers to the amount of work that a molecule can do when it breaks into simpler molecules or atoms. There is nothing distinctive about this form of energy except its source. When two or more atoms are combined into a molecule a certain amount of energy has been used in the process. It will remain in the molecule until part or all of the atoms are released from the molecule, and when they are thus released, a given amount of energy is available to be used in the chemical industries, or to sustain life, or it may be returned to the atmosphere. Energy is thus defined by what it is able to do and our interest centers around the source of the energy that keeps our bodies going, and around the manner in which it is used.

Possibly the simplest approach to this biochemical question "What makes the body go?" in

reality the Law of Metabolism, is through a study of respiration. Respiration is clearly a vital process that takes place within the living cells in which oxygen reacts on carbon and energy, in the form of heat, is supplied. Oxygen exists in the atmosphere as o_2, molecular oxygen, and in very small quantities as o_3, ozone. When these two chemical bodies are brought in contact with living protoplasm, more heat is furnished by o_3 than o_2. If this difference is computed, there are found to be 32,000 more energy units. (Calories.) At first thought this seems to be a very great difference, but if an equal amount of coal is burned with o_2 and the same amount could be burned with o_3, there would result approximately 20 per cent more heat. The percentage of difference is probably much higher in living protoplasm but not as great as one would infer from the figures 32,000. The important fact to be remembered from this illustration is that heat is constantly being given off to our bodies as certain groups of molecules undergo simplification. This is the source of the energy, then, that furnishes heat to keep our bodies going.

The source of the energy for bodily movement, growth and repair of tissues is to be found in the inanimate food molecules which in turn derive their energy from the process by which they are manufactured. Food energy in its relation to

vital energy can be studied like other forms of energy, but there is a specific work accomplished by living protoplasm only. This being the situation it is pertinent to inquire into some of the details of food manufacture, definitely illustrating this specific work.

There is in every country, even in time of famine, an abundance of the chemical molecules necessary for the manufacture of food, if these can be brought under the influence of living green plants. Unless these chemical bodies are thus treated, they cannot be used as a source of energy for living protoplasm.

What is the plant's mechanism that plays such an important rôle in the life of man? In figure 16 is shown a section of a plant leaf containing cells, each with a cell wall, cytoplasm, and nucleus, parts found in all typical cells (figures 4-8); but in addition there are several distinct bodies in the cytoplasm which botanists have named chloroplasts. These chloroplasts are usually bright green in color due to the presence of a pigment commonly known as chlorophyll. This pigment can be dissolved, leaving the chloroplast unchanged in form. They do not have any constant shape or size when examined in different plants. Their chemical composition is very complex, but similar in all instances.

It is not, however, in their shape and composi-

tion that our interest lies, but in the changes that take place within them. When water (a chemical compound, H_2O) and carbon dioxide (a chemical compound, CO_2) both enter a chloroplast in the daytime, a series of chemical changes follows that results in the production of carbohydrates.

This chemical body possesses more energy than was present in either water, carbon dioxide, or both. This new chemical body thus formed can do more work than the bodies from which it is formed. In the manufacture of this food, the sun furnishes the heat and light energy that is necessary. Science has been unable to detect as yet just what amount of energy or effect the living protoplasm contributes to this process that has such far-reaching influence on all forms of life. After the simple sugars have been formed in the chloroplast, the surplus of material thus manufactured is further modified by the living protoplasm of the plant into either fats such as oils or into proteins by joining nitrogen and sulphur to the sugar molecules. The details of these changes are for the most part unknown. (Figure 16.)

The net result of the changes that occur in the living cells of plants containing chlorophyll is that a given amount of energy has been captured, recombined, and put into such form that living things can use it. A daisy and a bean growing in the same field have these chlorophyll bodies and both

manufacture food. The products, however, are not of the same value. Science and experience have selected a large number of plants whose products are valuable to man and domestic animals. The mere mention of wheat, oats, potatoes, barley, buckwheat, corn, rye, sugar, apples, bananas, etc., sufficiently emphasizes their importance in maintaining life. There is no known process by means of which man with all of his scientific and inventive skill can manufacture one of these food products as do the green plants.

It has been well said that a plant cell containing chlorophyll is the "chemical laboratory in which was manufactured the food of the world." In these microscopic cells containing bodies rarely seen except by those taking courses in botany, is decided the fate of nations. They cannot be hurried in their work nor can they be compelled to work in eight-hour shifts, three shifts in twenty-four hours; but as of old, long before man lived on earth, in the North Temperate zone, they work only during the summer. The increase in the production of any of the necessary foods, then, must wait upon the activity of uncounted billions of microscopic cells that work only in their season. When the chemical changes thus dependent upon living protoplasm have taken place, the product can be stored for longer or shorter periods of time. Apples and potatoes will last till the next

season, sugar can be extracted and kept indefinitely, while the energy of coal was formed in plant cells back in the carboniferous geological period.

The terms proteins, carbohydrates and fats, just used, refer to the way that certain atoms are grouped in the chemical molecule. A common protein is white of egg or lean meat; while sugar and starch represent the carbohydrates, and olive oil and butter are typical fats. There are many different kinds of food, but all can be classified under one of these three groups. This does not mean that all of the proteins or fats are identical—they are not; but simply that the chemical elements, oxygen, hydrogen, carbon, etc., for example, are united on a certain fundamental plan with many variations.

One might visualize this theoretical chemical conception by taking six blocks of one size and shape, ten blocks of another size and shape, and five more differing from the first two sets. With these twenty-one blocks various shaped buildings might be made. The carbohydrate molecule ($C_6H_{10}O_5$) contains six atoms of carbon, ten atoms of hydrogen and five atoms of oxygen. The blocks may be used to suggest that different results can be secured by varying the arrangement of the three parts of carbohydrates. In a similar way one can understand how fats may be different. Proteins are much more complex and consequently

there is a wider range of variation among them.

The term food has been given a restricted use in the preceding paragraphs. In its broader usage, oxygen, water, salts, vitamines, etc., are foods if they furnish energy to protoplasm. None of these can be included under a classification of foods proper although they supply an indispensable need.

Most of the foods of man exist as mixtures of all of the three classes as the following table indicates:

Table 1.—Comparative Composition of Some Common Fruits.*

Fruit	Protein, Per Cent.	Fat, Per Cent.	Carbohydrate, Per Cent.	Calories, Per Pound.	100 Calory Portion, Gm.
Bananas	1.3	0.6	22.0	447	101
Grapes	1.3	1.6	19.2	437	104
Plums	1.0	..	20.1	383	118
Cherries	1.0	0.8	16.7	354	128
Pears	0.6	0.5	14.1	288	158
Apples	0.4	0.5	14.2	285	159
Oranges	0.8	0.2	11.6	233	195
Peaches	0.7	0.1	10.8	213	213
Lemons	1.0	0.7	8.5	201	226
Muskmelons	0.6	..	9.3	180	252
Strawberries	1.0	0.6	7.4	169	269
Watermelons	0.4	0.2	6.7	136	332
Potatoes	2.2	0.1	18.4	378	120
Sweet potatoes	1.8	0.7	27.4	558	81

* Taken from data compiled by Sherman, H. C.: Chemistry of Food Nutrition, New York, 1912, p. 319; from Bull. 28, Office of Exper. Station, U. S. Dept. Agriculture.

When these foods are taken into the digestive tract, they have to undergo a definite series of digestive changes before they can be absorbed into the blood. These take place first in the mouth of man, where the saliva helps to change the starches into sugars—a change which is chemical in character. In the stomach, the proteins are partly transformed and all three are fully digested after they reach the small intestine.

The conditions under which these changes take place are fairly well understood. All of them can be and have been duplicated many times in test tubes in the laboratory. No one has ever seen any explosions result from unsuitable combinations of the various foods nor will there ever be any, notwithstanding that they are said to be of common occurrence, if one may believe the advertisements of some of the new food faddists. After the food has undergone the same kind of chemical re-arrangement that it has been undergoing ever since there was a human stomach and undergoing the same re-arrangements that it will have to undergo in the digestive canals of men in the future, it is absorbed and passes into the blood.

As the blood courses through the body, it finally enters into the capillaries and is collected by the veins to be returned to the heart. It now passes to the lungs where a fresh supply of oxygen is secured and some waste products are given off,

then it returns to the heart to travel through the body again. The route in the body is relatively very long and yet about 23 seconds is all of the time required to traverse it entirely; while the blood can flow from the heart into the lungs and back again in less than 6 seconds. In the capil-

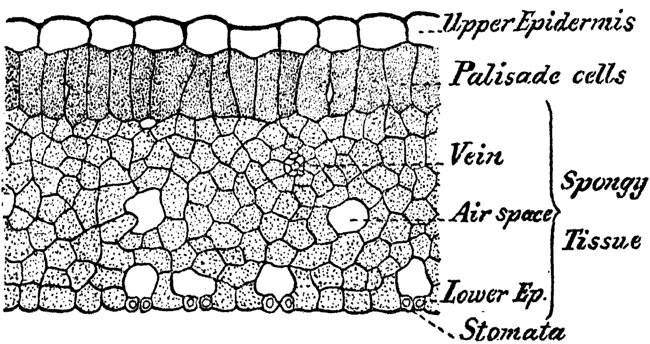

FIGURE 16. Section of the leaf of a plant. In such cells as these in the leaves of wheat, oats, corn, etc., are manufactured not only the food of man and animals but of the plants themselves. After all of these centuries man must wait for the season of harvest time when he gathers the product of these living cells.

laries, the flow of the blood is slightly slower than elsewhere. It takes about one second for the blood to flow a distance equal to the thickness of an ordinary lead pencil, but even so the cells must secure their necessary food from a rapidly flowing blood stream as it rushes by them. Unless it is conceded that certain

cells have a special selective capacity in taking food from the blood, it is impossible to conceive how one set of cells, like the brain, for example, can be furnished with a specific food. There is no evidence that this is the case. There is also no evidence in support of the popular contention that the brain cells need a special kind of food even if there were some special mechanism that would assist them in taking it from the blood stream.

When a group of foods is chemically analyzed, it is found that they are very similar as the following table shows:

Table 2.—Ash Constituents of Some Common Fruits.*

Fruit	Ash Constituents of Fruit in Percentage of the Edible Portion							
	CaO	MgO	K_2O	Na_2O	P_2O_5	Cl	S	Fe
Bananas	0.01	0.04	0.50	0.02	0.055	0.20	0.013	0.0006
Grapes	0.024	0.014	0.25	0.03	0.12	0.01	0.024	0.0013
Plums	0.025	0.02	0.25	0.03	0.055	0.01	0.	0.0005
Cherries	0.03	0.027	0.26	0.03	0.07	0.01	0.	0.0005
Pears	0.021	0.019	0.16	0.03	0.06	0.	....	0.0003
Apples	0.014	0.014	0.15	0.02	0.03	0.004	0.005	0.0003
Oranges	0.06	0.02	0.22	0.01	0.05	0.01	0.013	0.0003
Peaches	0.01	0.02	0.25	0.02	0.047	0.01	0.01	0.0003
Lemons	0.05	0.01	0.21	0.01	0.02	0.01	0.012	0.0006
Muskmelons	0.024	0.02	0.283	0.082	0.035	0.041	0.014	0.0003
Strawberries	0.05	0.03	0.18	0.07	0.064	0.01	0.01	0.0009
Watermelons	0.02	0.02	0.09	0.01	0.02	0.01	....	
Potatoes	0.016	0.036	0.53	0.025	0.14	0.03	0.03	0.0013
Sweet potatoes	0.025	0.02	0.47	0.06	0.09	0.12	....	0.0005

* Sherman, H. C.: Chemistry of Food and Nutrition, p. 332.

The chemical elements found in these foods are the ones that are most abundant in living protoplasm and in nature. (Fig. 17.)

When man is sick of fever for some time, there is a marked loss in weight due to the fact that first the fat and later part of the muscle tissue has been used to supply the abnormal amount of heat. In

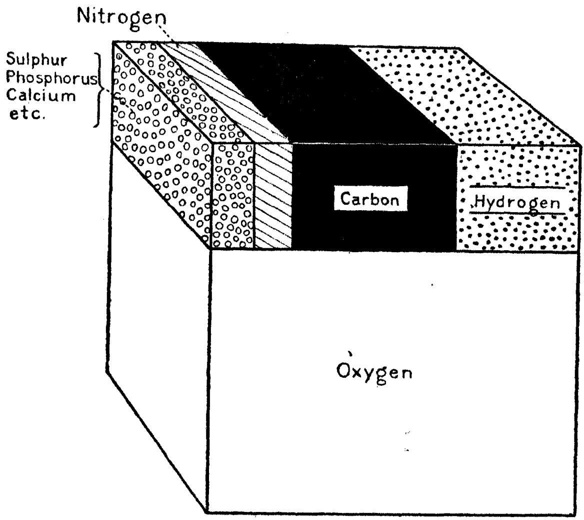

FIGURE 17. Diagram to show the proportionate amounts of chemical elements in living things. The human body is composed of these elements in the following proportions: Oxygen, 72%; carbon, 13.5%; hydrogen, 9.1%; nitrogen, 2.5%; calcium, 1.3%; phosphorous, 1.15%; sulphur, .147%; potassium, .026% iron, .01%.

repairing such a loss proteins are needed to make good the wasting away. This use of proteins and the service which carbohydrates and fats do in furnishing heat and energy for the contracting

muscle, is about as far as science has advanced in explaining what makes our bodies go.

In living processes, there always remain waste products. Between the stage where foods are actually built into living protoplasm and the formation of wastes, there is a gap in our information. Non-living bodies never form wastes and there is no parallel between the wasting away of rocks and the use of this term in connection with living matter. The waste products of protoplasm cannot be used by the same organism that produces them. Yet carbon dioxide, the waste product of respiration in all forms of life, contains energy which the green plant in a different vital process must have if it is to manufacture food, which emphasizes the intricacy and mutual dependence of living things.

All of the results of the studies on what makes the body go mean that one cannot get something from nothing. There is no patented road to health. After a time adequate food, hygienic living and rest are all unsuccessful in preventing the end. Life ceases while the body is abundantly supplied with food energy, which suggests that different methods must be devised before man unravels the mystery of death.

The numerous experiments of Atwater, Benedict, and others indicate clearly that there is more energy in the food which man eats than is rendered available by the metabolic process. These studies are particularly enlightening as we

argue for efficiency on the assumption that a high percentage of efficiency is the normal and natural condition of man. Efficiency is rather an acquirement based on the principles of education and not a process which takes its origin in normal protoplasmic activities.

When the several kinds of food of man are digested, a varying residue remains which is never absorbed and constitutes the main part of the excreta. One of the few studies which have been made on the digestive efficiency of man indicated that 92 per cent. of the proteins, 95 per cent. of the fats and 98 per cent. of the carbohydrates, when eaten in a mixed diet, were digested. This is probably higher than in the average human being. This residue is characteristic of all animals even though it contains a great deal of energy exactly like the energy in the digested foods that are absorbed. We are familiar with this phase of metabolic inefficiency. But let us examine the second step in the progress of the digested food. Consider the peptones. Several of these have become so simple, chemically considered, that they must in turn be built up into complex molecules before being useful. It is a well-known chemical principle that a great deal of energy is required to join atoms to a molecule, so that we have to record that it costs the living machine energy to build up these simplified digestive products into

chemical bodies approximating in complexity protoplasm itself. This is the second well-known source of metabolic inefficiency. One more will be mentioned.

During oxidation and the utilization of nitrogenous foods but a small proportion of the energy in the food bodies from which the energy is supposed to come is actually used. Some writers place the chemical energy thus used between 25 per cent. and 30 per cent. of the total amount in these food bodies. This is a startling revelation of inefficiency.

In so far as the fundamental principles of metabolism are concerned, they reveal that man is certainly very inefficient in his ability to utilize the available energy in his foods. It is doubtful if 15 per cent. of the total amount of energy in the food as it enters the digestive tract actually contributes to the life of man. Steam engines are from 24-25 per cent. efficient; gasoline engines 20 per cent.; the Liberty Motor 23 per cent., typical examples of mechanical efficiency. Linehart, 1920, concludes from his study of the bacterium, Azotobacter, that it is 1 per cent. efficient in its ability to fix nitrogen in a solution of mannite.

Enough has been presented concerning what makes the body go to indicate that there is a limited source for all of this energy and that it

must be subjected to important changes before it contributes to sustaining life in protoplasm. In these several processes there is a great percentage of waste or inefficiency. We are accustomed to think of man as the highest act of creation—the most perfect of animals, and it comes as a great shock to realize that when considered from the modern standpoint he is scarcely 15 per cent. efficient in his metabolic processes.

Some natural inferences follow: First, we must expect that remedial and corrective changes in our diet will yield slow and small results. There is no way of revolutionizing these fundamental processes. No one has invented any special food that sets aside processes or enables the body to secure a special amount of energy. These facts furnish the basis for correctly valuing all special, patented foods whether prepared to nourish the brain or make brawn. They don't do it any more than ordinary foods, and, in most instances, much less. The recognition and application of these principles would save mankind a great deal of money.

Secondly, we cannot claim to be educated and be ignorant of such basal relations. Education is constantly aiming to adjust man to his environment; while our wilful ignorance contributes to a mal-adjustment in which our efficiency never reaches the high plane it should. There does not

seem to be much to encourage man that his metabolic efficiency will ever be higher. It is often much below normal in cases of fatigue and indigestion. Our problem is to keep it as nearly as possible normal for us as individuals. We have no knowledge of how much better off man would be if he were twice as efficient metabolically. What he could do under such conditions is pure speculation. The stern fact that we must realize, however, is that he must do his work under these conditions which we have become accustomed to speak of as normal and to think of as 100 per cent. efficient.

Thirdly, the mere fact that man has to eat in order to secure adequate energy to keep his living machine going has resulted in forcing nature to devise methods of ridding the body of all this unusable energy. So we have hundreds of thousands of sweat glands and the lungs and kidneys devoted to keeping the living protoplasm free from the poisonous effects of the accumulations of energy that cannot be utilized within the body. Herein lies the secret of much of human ills. The wastes of metabolism are frequently not properly removed from the body. Man is so constructed that he cannot store these products within his body as do butterflies, in part, where we find the scales on their wings containing leidotic acid, a metabolic waste product.

Fourthly, intimately associated with the removal of wastes is the important fact that the several digestive fluids are not used or modified during the digestive processes. After they have caused the appropriate changes in proteins, carbohydrates or fats, they in turn are cast off from the body as waste, although as useful as digestive agents as ever, which seems to be the climax in efficiency.

This brief study of what makes the body go reveals again man's similarity to other living things, and his dependence on them for his sources of food energy. The vital processes responsible for keeping the biological unit working for man's welfare are very old and have never been improved upon since civilized man emerged from the savage state, nor may we ever expect these elementary processes to be altered. Our attitude toward them should be much like our recognition of the law of gravitation—we having become adjusted to it through education and experience. For the ignorant and foolish, laws have been passed to protect them from the harm that might come from their disregard of nature's laws. We have been too reluctant to recognize that man, himself, is regulated by similar basic laws and practically no preventative steps have been taken for his protection. This is imperative as the next move forward in civilization.

CHAPTER V

THE LAW OF BIOGENESIS

THE first law of protoplasm has been accepted for over fifty years. (See page 13.) It has always been recognized as applying to man. If our information of the working of this law were limited to a study of man, little would even now be known. Simpler animals can be studied and all of the steps in reproduction recorded because a large number of the stages take place either outside of the parent or in organs easily prepared for observation.

We all recognize that a clear understanding of this basal law has an important bearing upon our happiness. So little information is actually available except to the technical scientist that this phase of man's education has long been deficient through no fault of his own.

In any explanation of the application of this law, it is easier to begin the study with the conditions that are found in plants and animals and leave the specific application to man for a separate discussion.

As soon as one fixes his attention on an organism

that has several tissues in its body, he observes a marked distinction between the cells that are devoted to carrying on the daily activities of living and those that become active rhythmically, such as the cells that produce the blossoming flowers in spring.

The cells that keep the body alive and are busy in digesting, breathing and responding to the manifold stimuli of their immediate environment, grouped into muscle, nervous, skeletal and various other tissues, or leaves, branches and roots, are termed the somatic or body tissues. This variety of activity results in producing cells that become highly specialized. Of course such cells constitute the bulk of the body of plants, animals and man. They are by far the most highly differentiated tissues and their cells participate in vital processes that are extremely difficult of description.

In marked contrast with these highly specialized cells, that one can readily recognize at a glance under the microscope, are the relatively simple cells, termed the germ or reproductive cells. The germ cells never unite to form tissues and never participate in such general bodily activities as movement, food-getting, excretion, etc. Their activity is periodic even in aquatic animals in tropical waters, where they are recorded as producing young at regular intervals.

During the remainder of the time, these germ

cells are inactive except in the sense that they may be growing into mature germ cells to take the place of those that were set free at the last period of activity. Encased within special organs such as the ovaries or spermaries (testes), these cells are nourished and protected by the rest of the organism. It has frequently been suggested that the germ cells are in a real sense parasitic upon the body as they do not help to keep the body machinery running but help only to form a new individual. Such a statement assists one in visualizing their dependency upon the other parts of the body.

There is still another fundamental relationship that it is desirable to keep in mind, and that is the obvious simplicity of structural relationship between the several germ cells themselves in each ovary and spermary. In these organs, each germ cell persists as an individual and never unites with any other similar cell. There may be 2, 4, 100, 1000 germ cells in one of these structures, but each one is distinct and living as a unit. This is, then, in complete contrast to all of the other cells of the body. The result is that the germ cells remain simple and primitive. As they do not participate in the bodily activities, it is difficult to conceive how they may become influenced by what the body does.

One must think, then, of numerous germ cells,

nourished and protected by the body of the plant or animal, and periodically becoming active, some once in twelve months, others once every month. In most plants and all of the lower animals, reproductive activity is seasonal. This is especially apparent in many of the sea forms which grow elaborate bodies whose sole work seems to be the production of germ cells. As soon as this great task is complete, they droop, wither and die—a fact strikingly shown in such simple animals as the hydroids which are related to the jelly-fishes and corals. These beautiful plant-like forms attain to a luxuriant growth in June and July along our Northern Atlantic coast, producing great quantities of germ cells. After these are set free, the parent organisms waste away and disappear. In the simple forms of plants and animals the production of new individuals is the supreme act of life.

The power to form new individuals like the parent or parents is a universal feature of living things. The animal or plant that cannot do this becomes extinct and all that can be said of it is that it once lived. Instead of reproduction some writers use the term "instinct for perpetuation." Reproduction is one of the fundamental characteristics of living protoplasm that in some instances becomes so complex that special terms are needed to describe the process. Without this power to

form new generations there would be no such thing as we now recognize as living protoplasm. This feature of life is to be considered in just the same sense that one regards the power of living things to secure nourishment, to respond to stimuli, etc. It is a grave mistake to try to separate reproduction from the other characteristics of life and discuss it as something special. It can never have its correct relations except when the several aspects of life are considered together.

Let us examine these germ cells in some detail in order that there may be a foundation for understanding the marvelous results that come from them. The egg cell or ovum is the more satisfactory for beginning this study because of its size. In Fig. 18 is shown a photograph of a small, rounded cell with a conspicuous nucleus and a relatively small amount of cytoplasm. This is a young stage in the growth of the egg cell of one of the common worms. For a long time, possibly several years, this cell was cylindrical in shape and smaller than it is now. There were many other cells just like it in the ovary of the worm. Neither internal nor external agencies are held responsible for selecting this cell from the many others to become changed into a germ cell. When such cells are studied, the larger rounded ones are the ones upon which attention is fixed. In Fig. 19 a later stage in the growth of an egg in this same animal

FIGURE 18. A very young egg-cell of one of the common earthworms showing cytoplasm, nucleus and nucleolus. Photomicrograph by Foot and Strobell. Especial attention is called to these very fine photographs in Figures 18-22, all of which are by the same authors.

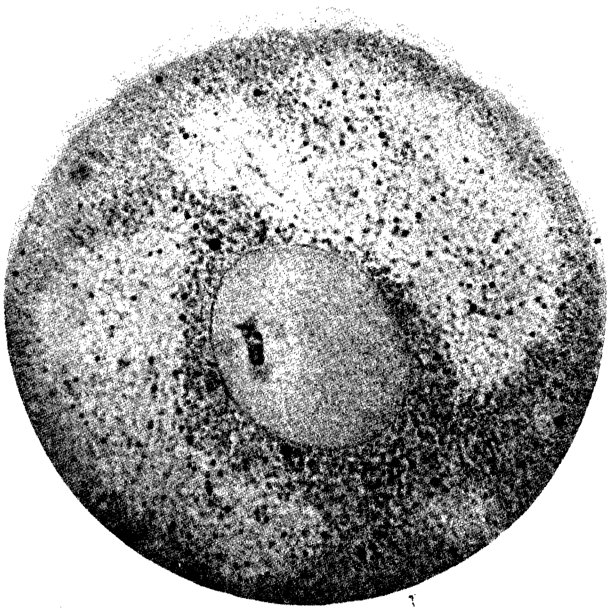

FIGURE 19. A photomicrograph of the same egg after it has become full size.

is shown. The nucleus is larger and the cytoplasm has increased greatly. The cell is still a unit and the only change is an increase in size in the two parts of the cell. But how did these parts come to grow in this fashion?

Only a partial answer can be made to such a question. Much of this growth consists in the accumulation of food energy. The body of the animal furnishes the necessary amount of food which, on reaching the egg cells that are to grow to maturity in a given reproductive cycle, is elaborated into living egg-protoplasm. This energy is stored in the cytoplasm and is one of the earliest instances of preparedness on record.

The next three figures, 20-21-22, introduce us to a technical phase of reproduction but one necessary to the discussion if we are to have any comprehension of the modern problem. In the nucleus of all cells is found a complicated structure that undergoes various changes. This substance is given two different names which are to be regarded as descriptive terms for the same substance at different stages of activity. These two terms are chromatin and chromosomes. In Fig. 18 the nucleus has scattered granules with no constant arrangement. Each of these granules takes a certain kind of stain or dye when prepared for study. Such granules are termed chromatin granules. When a number of nuclei are studied,

it is noted that the individual granules do not have any specific relationships to one another except for a brief period when the cell is dividing. (Compare Figs. 20-22.) These chromatin granules, in anticipation of the dividing of the cell, at certain intervals take a definite position and become greatly altered in appearance. Fig. 20 shows the granules arranged in bands. Each band is double, due to the splitting of the chromatin granules. In Fig. 21, these same bands are shown. Each one has become more compact and much shorter. In one the double condition is still evident. At about this stage of growth, the nuclear wall breaks down and the contents of the nucleus and cytoplasm are more closely associated. Such a condition is shown in Fig. 20. An important fact to keep in mind at this point is that these bodies retain their individuality after the nucleus breaks down. The descriptive term now employed for these bodies shown in Figs. 20-22, is the word chromosome.

It is known that there are a definite number of chromosomes for each species of animals; for example, man has 48, the frog 14, many snails 32, some worms 4, while one of the simplest animals (paramecium) has more than 100.

When the earliest students first began studying the nucleus, they little dreamed of its complexity.

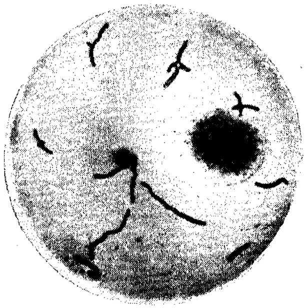

FIGURE 20. A greatly enlarged photomicrograph of the egg-nucleus only of the egg shown in Figure 19. This shows some of the wonderful complexity of the nucleus. Notice particularly the double strands of chromatin.

FIGURE 21. The same as Figure 20 but now the long strands of chromatin have become much shorter and denser so that they take a deeper stain.

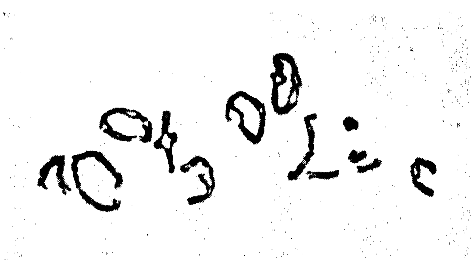

FIGURE 22. The chromosomes lying free in the cytoplasm and beginning to separate, the first clearly marked step in the division of the cell.

The deeper one goes into this phase of Biology, the more complex it becomes.

If one now considers the structure and origin of the sperm cell, it is found in its early stages to be similar in form and size to the young egg-cell (Fig. 18). In fact one cannot tell by the appearance of the earlier stages whether the cell will grow into an egg or give rise to sperms. Sperm cells become modified for locomotion as they must make their way in the water, through plant tissues, or move along passages until they come in contact with the egg.

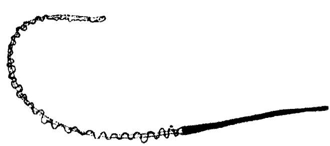

FIGURE 23. The sperm cell of a Salamander. The long, black region represents the nucleus and is the only part that participates in fertilization.

Fig. 23 is an enlarged drawing of a sperm cell of a salamander. It consists of a head, middle piece and tail. The head is the condensed nucleus and consists of a compact mass of chromatin; the tail is all that remains of the cytoplasm; while the middle piece is a minute structure intimately associated with the future division of the cell.

Omitting the technical aspects of some of the details, one can now make a comparison between

the egg cell and sperm cell. In so far as the parts are concerned, the two are equivalent. Each has a nucleus and each has cytoplasm. But when one asks, are these two dissimilar looking cells equivalent, the answer must be no. Upon this point

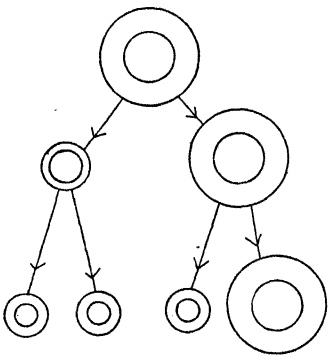

FIGURE 24. Diagram to show in outline some of the changes that the egg passes through in preparation for fertilization. The first division results in the formation of a small cell and a large cell. The small cell is called a polar body. Later it divides. At the same time the larger cell or the egg cell gives off a second polar cell. In the giving off of these two small polar cells, there is a reduction in the chromosomes. The three polar cells play no part in the development of the embryo. They are discarded and die. After these elaborate changes, the egg can be fertilized.

there is general agreement among scientists. To make this clear, the following details are necessary:

Before the egg and sperm can unite in fertilization, the egg passes through an elaborate prepara-

tory process. The nucleus is the center of these preparatory changes which have for their main purpose the elimination of a large amount of chromatin. In accomplishing the elimination of this chromatin, some of the actual chromosomes are

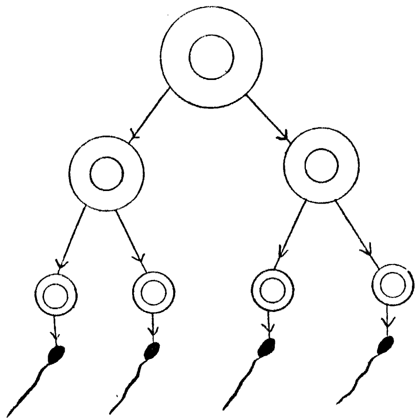

FIGURE 25. Diagram to show in outline some of the changes that sperm cells pass through in changing from a typical cell into the mature sperm. In this process each sperm-mother cell gives rise to four mature sperms, each of which is capable of fertilizing the egg. As the growth changes take place, there is a sorting and reduction of the chromosomes so that each sperm has but one-half as many as the sperm-mother cell. It has also been shown by recent studies that the sperms are not the same in the nature of their chromosomes.

cast out of the egg. The result is that the egg comes to have a nucleus that has but one-half as much chromatin and one-half as many chromosomes. The diagram in Fig. 24 indicates how

it is possible to bring about such results. It is necessary to keep in mind the fact that the chromatin increases in amount during these changes through a natural growth process. After elimination of chromatin, the egg is now ready to be fertilized. It has been prepared for this important event.

The sperm in a similar manner passes through special growth stages which result in a similar reduction in the chromatin. There is this important distinction between the changes which take place in the egg and those which occur in connection with the sperm: instead of there remaining a single egg and three abortive or diminutive eggs, the "polar cells" of the diagram, there are four active sperm cells, each of which is capable of fertilizing an egg cell. When the division in the growing sperm cell takes place, resulting in separating the chromosomes into different sperm cells, Fig. 29, there are produced sperms with a different chromatin content. This enables one to state then that the sperms of a given generation are not all composed of exactly the same kind of chromatin. The several changes just briefly given in the egg and sperm are limited to the nucleus. (Fig. 25.)

The fundamental facts in connection with the preparation for reproduction in the egg and sperm are of the utmost importance. Around these facts center the whole of our present-day interpretation of heredity and sex.

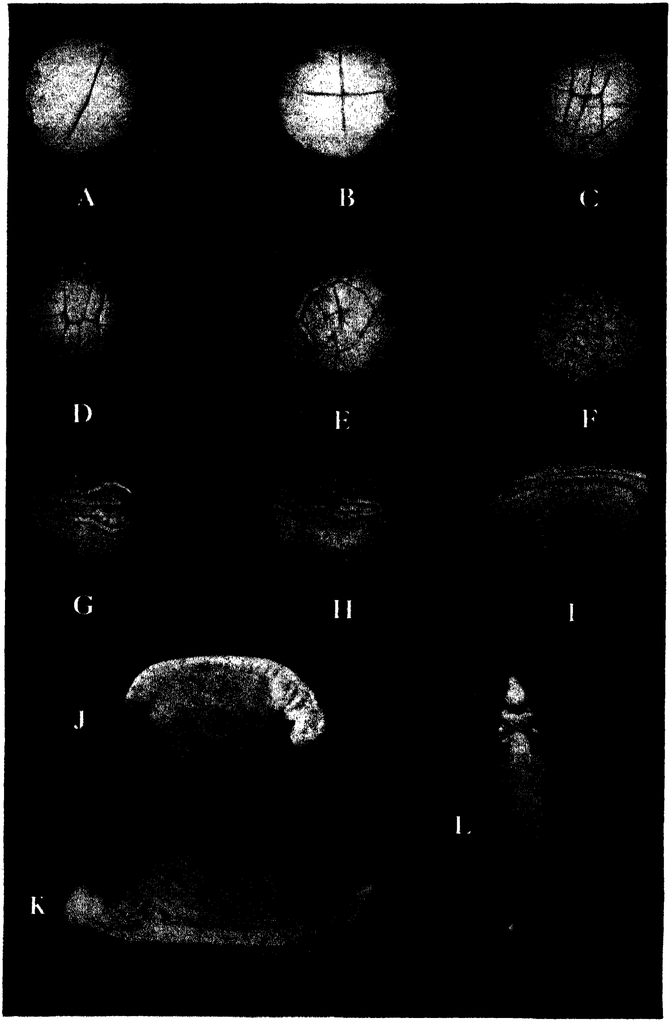

Figure 26. See reverse side for caption.

FIGURE 26. In A is shown the embryo of a salamander that is just beginning to form the first two cells. In B the second plane of cleavage is just beginning and is at right angles to the first. This is termed the four-celled stage. C, D, E, and F, later segmentation stages of this embryo. Notice that the cells are gradually becoming smaller. G shows an early stage in the development of the central nervous system, a stage which occurs much later than the one shown in F. In H the edges of the ridges which have thickened to form the nervous system are drawing together; and in I they are united except in the brain region. At this stage it is easy to distinguish for the first time the cells which are to differentiate into the most highly specialized cells in the body of animals, the nerve cells. J, L, and K represent three stages of the embryo after the nervous system has been formed. In J the body of the embryo is forming on the surface of the yolk. L, ventral view to show the formation of the mouth. K (upside-down in the cut). The tufts arising from the neck region are gills and just back of them the front limbs are appearing. On the lower surface of the head is seen a small pit; this is part of the mouth. Just above this pit can be seen a faint circle which is the eye. Better seen in J. Photographs by B. G. Smith.

After all of the elaborate changes just outlined have taken place, the sperm can fuse with the egg and fertilization is accomplished. (Fig. 30, opposite page 90.) Fertilization is really the union or re-mating of the chromosomes of the egg and sperm into a single body, the nucleus. Thus is formed a nucleus that in its chromatin details is unlike any other nucleus that has ever been formed and is unlike any other that will ever be produced in the future. *Individuality has its origin in this union of sperm and egg nuclei.*

There are many differences between human beings, both evident and hidden. Size, weight, strength, agility are some of these variations that at once occur to the reader but the analysis may well be carried to the more minute differences in our sense organs, our reaction time to stimuli and the quality of our several physiological activities. These numerous differences are all determined when the male and female chromosomes unite in fertilization. So far as adult man is concerned, they are then already formed and fixed. They constitute his equipment and are subject to but slight modification by the processes of education.

The general statements just made, apply to man and to all animals and plants that reproduce sexually, which is the usual method. After the sperm has merged its identity with that of the egg, an embryo is produced that is capable of developing. *There is no specific time when life is added to this*

potential new plant or animal. Both the parent bodies, egg and sperm, were alive; and when they unite their living protoplasm, a new individual is produced that is alive. To destroy an embryo, then, is to destroy life.

In pointing out what happens after the union of the egg and sperm, some illustrations in the development of the large American salamander are given. These photomicrographs show some of the external changes which the embryo of this animal passes through. In Fig. 26-A note that the mass is being cut into halves. This will result in forming an embryo whose body consists of two cells. Such a figure only indicates some of the superficial changes; more important ones are taking place within the nucleus. Some of the important internal changes are indicated in the excellent photomicrograph in Figs. 20-22. This is a picture of the separation of the chromosomes preparatory to the forming of the constriction in the cytoplasm as shown in Fig. 26A. There is formed an elaborate mechanical structure whose main purpose is to distribute the chromatin in equal amounts to the new cells that are to form. (Fig. 26G.) By this means each nucleus in the embryo is furnished with the same number of chromosomes. Every cell of the many thousands of cells in the body of man has the same number

of chromosomes as a result of this method of division.

In these external and internal changes in the embryo there is a type of energy at work found only in living protoplasm which is explained in part in the chapter "What Makes Our Body Go." Some additional facts are explained in the chapter on Heredity and much remains that is not understood.

The next stage in the division of the salamander embryo produces four cells. (Fig. 26.) The later stages are irregular in the order of their appearance and unequal in the size of the cells produced. (Fig. 26 C-F.) Such early irregularity in the shape of cells in the embryo is not a constant feature in the development of animals but is peculiar to the salamanders and some fishes.

As the growth of these cells continues, many cells are produced, the size of the embryo increases and takes on a specific shape. Finally a conspicuous groove appears on one surface (Fig. 26 G-I), which gradually changes until it becomes enclosed within the body of the embryo. One can now recognize a head and tail region at this stage. What is this groove on the outside of the embryo? It is the first stage in the growth of the nervous system of this salamander. The nervous system, then, is produced by the same kind of cells that

later in the growth of the embryo are transformed into the skin. In the mature condition of the nervous system, surrounded as it is by a definite number of bones in the skull, no one would think of suggesting that it is derived from cells like those that form the skin, unless he knew of these clearly defined changes.

Soon after this, the embryo has a long tail and gills for breathing. But it does not look like its parents except in a very general way. It is now in the tadpole stage which lasts for nearly two years, after which the body becomes like the parent. (Figs. 26 G-K-L, 27.)

In many of the details, the facts mentioned in the development of this salamander are similar in all animals with a backbone; in the stages shown in Figs. 26 A-B-G-H, the changes are similar to corresponding stages in all animals. On the other hand, so distinctive are the embryonic changes, that one has no difficulty in distinguishing the embryos of the fish, the frog, the reptile, or man. There is an individualistic feature in the minute changes in development that is characteristic of each species.

SUMMARY

During the past twenty-five years scientists have accumulated a vast amount of information about the embryology of animals and plants. They have come to know the order in which events

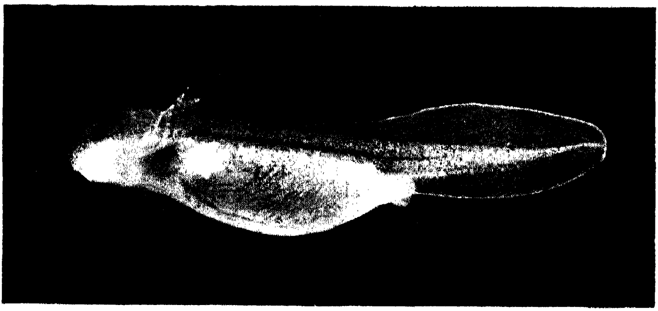

FIGURE 27. The salamander embryo has become a free-swimming animal with well-developed gills and sense organs. The blood vessels seen in the light area are formed especially to absorb the yolk. The salamander egg contains enough food-energy for these numerous growth changes. Photograph by B. G. Smith.

normally occur, even in confusing detail. What causes this orderly sequence of changes in the development of all living things is a question still unanswered.

All know that no form of life comes into existence except through the division of some preexisting life (Biogenesis). All know that these same forms of life go out of existence either by a division of one individual into two as in Protozoa, Fig. 12, or by the disintegration of the unity of action of the cells composing the complex body, namely, by death. When one comes to ask how living protoplasm came to behave as it does in reproduction there is as yet no scientific answer.

CHAPTER VI

REPRODUCTION IN MAN

THE scientific conception of reproduction is an important part of man's education; it places the emphasis on the essential and fundamental

FIGURE 28. Diagram of the human sperm cell in its fully developed stage. Compare the shape of this sperm with that of the salamander in Figure 21. The round head of the human sperm cell contains the chromatin material and is the only part that participates in the actual process of fertilization.

features of the Law of Biogenesis as it relates to mankind. This age-old question, abused and tabooed, has finally been solved so far as science can contribute to its solution. This does not mean that all of the problems of reproduction are understood, but it does mean that we are able to describe clearly and simply this important phase of protoplasmic activity in man in a manner that will contribute much to his education. He can never be free from his animal ancestry and the basal laws that govern all life. The only alterna-

tive is to understand each one and recognize the part that it plays in our life.

Reproduction in man is identical with the same process in animals. The cells which give rise to new human beings are the germ cells, sperms and ova. These differ greatly in size. (Figs. 28-29.) It has been estimated recently that the volume of the human sperm is not over 50 cubic micra (a micron is 1/1000 of a millimeter), while that of the human ovum is 1,767,150 cubic micra, or over 35,000 times the volume of the sperm cell.

The human ova are grown in the two ovaries which contain approximately 72,000 ova at puberty. Each one is a minute, spherical body with a diameter of 1/5 of a millimeter (about 1/125 of an inch). It has the typical nucleus surrounded by granular cytoplasm.

The human sperm cell is a minute, elongated whip-like cell with one end enlarged. Sperms average about 1/20 of a millimeter in length (about 1/500 of an inch). The large end contains the nucleus.

Sperms are grown in the two spermaries (testicles or testes). There is no way of determining accurately just how many sperms a single spermary contains as new ones are continually being formed in some men, from the period of adolescence to old age. Professor G. H. Parker of Harvard

states, "It has been estimated that in the period of thirty years, between the twenty-fifth and fifty-fifth year of manhood, one individual will produce the prodigious number of 339,385,500,000 spermatozoa!"

It is immaterial whether these estimates for the

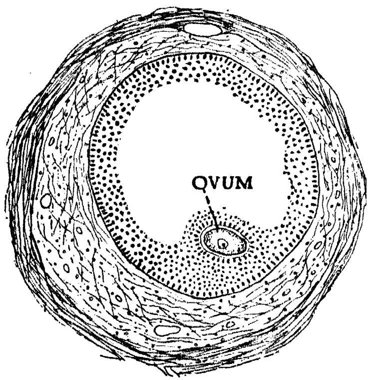

FIGURE 29. The human egg cell, the ovum, surrounded by several layers of special cells. Compare this cell with the one shown in Figures 4 and 16. The cytoplasm of this egg is not supplied with much nutrient material and the forming embryo must be nourished by the parent.

number of ova and sperms are correct or not; the essential fact is that a very large number of both are produced. The proportion that actually develops and shares in producing new human beings is so small that it constitutes a decided exception. The mere production of this vast number of living germ cells is the source of a number of our human problems of reproduction.

The second important fundamental fact is the elaborate care that nature exercises in arranging that the ovum must pass through a preparatory stage of development before fertilization can take place. During this stage, the same orderly process of removing chromatin from the nucleus of the human ovum occurs as in animals (page 79). Sperm cells, on the other hand, pass through a series of changes which results in differentiating the sperms into two classes: those that contain 23 chromosomes and those that have 24.

There is no choice on the part of man in the formation and preparation of sperm cells with 23 chromosomes, or of those with 24. Each one receives the same essential equipment, although but a few of the hundreds of thousands may ever participate in giving rise to a new human being. As each ovum is fertilized by but a single sperm, the proportionate number of sperms that ever play the part for which they are grown is very small. The significance of this statement can be made clearer by placing the number of children in a family as the numerator and the estimated number of sperms as the denominator of a fraction.

The only structure that the father contributes is the sperm. After the sperm cell has made its way through the uterine passage and come in contact with the ovum, the tail is lost and the head only enters the egg. Again consulting Fig. 30, it is seen that the sperm-head becomes transformed

into a typical nucleus. This nucleus has a definite number of chromosomes (23 or 24 in man) which now unite in a re-mating relationship with the egg chromosomes. In so far as the father is concerned then, the chromosomes are the only bodies that can be responsible for transmitting parental characters.

In this connection, we naturally ask, "What is the cause of maleness or femaleness, and can it be determined?" There have been more than one hundred theories which have had for their purpose the determination of sex. None of them has any standing to-day. The use of the phrase "determination" of sex is unfortunate because no one can in advance determine that an offspring shall be male or female. One gains a much clearer conception of the process if the word "explanation" is substituted in the above expression so that it reads, the explanation of sex. There is a large body of scientific evidence that sex is fixed when the sperm enters the ovum. In man, for example, if the number of chromosomes in the sperm is 23, the resulting offspring will be a male child. If the number is 24, the child will be a female. There is absolutely no way of predicting which number the impregnating sperm will have nor is there any way of influencing the result.

Keeping in mind these great, fundamental con-

ditions that always obtain in human reproduction, what is their bearing and application? The production of offspring is a universal process among living things. This process was a part of life from the very beginning and will continue to be inseparable from it to the end of time. There is no way by means of which the ovaries and spermaries can be prevented from producing their normal products except by certain diseases or an operation resulting in their removal. The reproductive process is thus a normal part of life. Remove it and there would result something different from life as it is everywhere known. It makes no difference whether one is willing to be intelligent upon this vital matter or not, the germ glands continue their normal activity. (Figs. 31, 32, 33.)

In the same sense that this process is universal, it is a natural and normal vital activity. There is no method known by means of which one can determine that a given sperm shall unite with a given ovum. There are thousands of sperms in a single emission but only one enters the ovum. Nature must be forever preparing normal sperms or the result would be a failure. This she seems to be able to do in unlimited numbers. If the statement that no two sperm-cells are ever identical be true, then there must be a large degree of chance as to which one of the many thousands will be suc-

cessful in entering the egg. It is evident that the result will be determined when this union takes place. If one wishes to be facetious, he can congratulate himself as to his existence and that he is what he is and not a different individual as he certainly might have been if a different sperm had united with the ovum because it is very generally accepted by scientists that nature never yet made two eggs or two sperms exactly alike.

As long as animals lived in the water, it was a simple matter to bring the sperms and eggs together. The fish deposits her eggs in the water and one or more males discharge vast quantities of sperms in the same vicinity. In a similar manner, the eggs of frogs are brought in contact with the sperms, water being the only medium necessary to bring the eggs and sperms together. But when animals came to live on land two new problems arose. One was that of bringing sperms and eggs together, because the cells are heavier than air and are unable to move about in the ground; the other was that of protecting and nourishing the embryo. The first stage in solving the latter problem consisted in furnishing membranes and shells, with adequate food for the embryo till it hatched. The eggs of snakes, turtles, and birds illustrate this stage. The highest form of protection to the embryo is in man where all of the embryonic changes take place in the uterus of the mother.

FIGURES 31, 32 and 33. See reverse side for caption.

FIGURE 31. A four millimeter human embryo. This is one of the smallest human embryos that has ever been photographed. Reproduced by permission of the Anatomical Laboratory of Chicago University.

FIGURE 32. An older human embryo. The eye is partly formed. The constrictions back of the eye are to become the gill slits. The knobs in the middle of the embryo and near the tail are the fore and hind limbs just beginning to form. Notice that the tail at this stage is longer than the legs. Reproduced by permission of the Anatomical Laboratory of Chicago University.

FIGURE 33. Turtle embryo of about the same size as the human embryo shown in Figure 32. The eye is much larger and the entire embryo is more advanced. These are all untouched photographs so that no one can have any question as to the actual existence of the structures shown

In order to bring the sperms in contact with the ova within the body of the mother special structures have been developed. In man these special structures are the penis and three special sets of glands, each with a separate work to do. These are called respectively Cowper's, the prostate, and the seminal vesicles.

An illustration may help us to understand the action of the glands. It is common experience to have the mouth water in anticipation of something delectable to eat. A watery fluid appears in the mouth in response to a stimulus from the brain. This stimulus is carried by nerves to the salivary glands located in the side of the mouth and also just beneath the ear. These glands manufacture a definite secretion which serves a useful purpose in the digestion of food. All secretions are made in living protoplasm that has become specialized to produce a specific product. Such glands do not act rhythmically or in an intermittent fashion but continuously. Their rate of activity depends in the main on the physical vigor and the demands upon the glands for their product. The sex glands produce their secretions in just the same manner as the salivary, pancreas or liver. The only distinction is in the use to which nature puts their products.

There is still one more fact to be kept in mind as we think of the activity of glands. In all nature

there is a rhythmic ripening and discharge of germ cells which is seasonal for nearly all of the plants and for most animals. Man is the only exception among the higher animals and even here the ova are regularly discharged, thirteen times a year. This is in marked contrast to the constant activity of the salivary glands.

There comes the age in every child when all of the sex glands become active for the first time. This is known as the period of puberty or adolescence, and usually comes on between the ages of 12 and 14 years.

With the onset of puberty, the germ glands, ovaries and spermaries become active. Cells begin to grow into mature ova or mature sperms for the first time. This was evident to the earlier students; but what eluded investigation for many years, was the formation of a fluid that is actually secreted by special cells of the ovaries or spermaries. This secretion is known to-day as the internal secretion of the germ-glands. It is distributed to all parts of the body by the blood and produces changes of far-reaching importance. Common observation of children at this period reveals their eccentricities, change of voice, growth of hair on the face of the boy; and the much more important change—the change into womanhood and manhood. This last change is the vital one,

for with it comes a subtle, slow transformation that is to endure until death.

Physically, there is a rapid period of growth, especially in the legs. A boy may grow three or four inches in a single year. He appears large and strong but in reality is unable to endure severe and prolonged labor as his energy has been so largely used in growing bone and muscle.

In addition to the physical changes, which have been elaborately catalogued by some writers, there are very important psychological transformations. Ambition, purpose, responsibility bud forth. A desire for independence and freedom from parental restraint are very common characteristics. The boy thinks of himself as a man and that he should be allowed to do as men do.

Similar statements can be made concerning adolescent girls. Their self-assertiveness and desire to have their own way is as obvious as in boys. With the activity of the ovary in pouring out its internal secretions, there usually comes an instinctive desire for attention from boys. Here is the root of the boy craze and foolish adventure. If these inevitable changes can be understood by the girl, they are recognized as but the budding of her womanly character. It is just as important that the girl have her mother's help and advice as it is for the boy to have his father's and her

friends must be selected with just the same care.

It took a long time to discover that there is a definite agent that is responsible for initiating the above changes in boys and girls at puberty. Now that the fact seems to be established, numerous questions of sex can be answered intelligently, and a rational basis furnished for our dealings with children passing through this period. It is just as if the body were being stimulated for the first time by some powerful medicine and the cells are all struggling to adjust themselves to this new condition. No one can anticipate just how the body of your child is going to react during this critical period, but you can help him to adjust himself if you can explain how the whole body is being stimulated by this internal secretion from the germ glands.

The activity of the secondary sexual glands in boys (prostate and seminal vesicles) is the immediate cause of the sexual desire. These glands are continuously active so that they are manufacturing their secretions day and night, day after day. After a time each becomes gorged with its own secretion. The result is that the glands are usually emptied during the night and the process is known as "nocturnal emission," or "wet dreams." The only thing that has happened is that these two glands have emptied their product in a normal and

natural manner. Through ignorance and a false conception of manhood, many boys are led into immorality in an attempt to prevent "wet dreams," an impossible task unless they carry self-indulgence to the limit.

When puberty begins in a girl, the ovaries discharge eggs usually thirteen times each year. Associated with this process are several other physical conditions, all of which are included under the term menstruation. This is a natural process which continues for about thirty years, there being no given age at which it ceases. Each period of menstruation lasts from four to seven days, during which time it is desirable to avoid becoming overfatigued. Lack of proper hygienic precautions is frequently the source of much suffering afterward. It is just as important that a girl should keep herself well and strong as it is for a boy; the greater responsibility in producing children must forever be hers.

For many years it has been customary to explain to children the necessity of cleanliness, care in eating and good manners; but to keep utterly silent on this vital and important part of their bodily activity. One of the reasons for this silence has been a lack of information in regard to the fundamental facts and inability to present the problem in an accurate and simple fashion. But

now that science has supplied these essential facts, what shall be done, when shall it be done and how shall it be done? These are questions of great importance and the answers given at this time may have to be altered with the accumulation of more information.

The following facts help us to know when sex instruction should begin. Dr. Exner made a study of 948 college men and the results are charted as follows:

THE AGE OF FIRST PERMANENT IMPRESSIONS REGARDING SEX

Age	Boys	
4–5	16	
6–7	108	
8–9	140	chart lines
10–11	193	
12–13	139	
14–15	41	

The average age at which 637 men received their first sex impressions was 9.6 years.

THE AGE OF FIRST PROPER SEX INSTRUCTION

Age	Boys	
6–7	7	
8–9	7	
10–11	32	
12–13	93	
14–15	225	
16–17	209	
18–19	105	chart lines
20–21	38	
22–23	6	
24–25	5	

The average age at which 727 men received instruction about sex from wholesome sources was 15.6 years.

It is readily seen from these facts that we have been beginning sex instruction from four to six years too late. College teachers have been dealing with sex instruction for many years, but their work comes after the damage has been done. Children from nine to twelve years old are in the grammar school. Practically all children begin adolescence before entering the high school.

For a long time parents and teachers deluded themselves into thinking that children of this age did not think about such things. The fundamental life processes remain the same and civilization cannot alter them. If the parent or teacher had but taken time to recall when and where he first gained his information, he would never have cherished this delusion. But a second scientific study gives more convincing evidence on this point. This deals with the source of the first information about sex matters. This is again a study of college men and it shows that 91.5 per cent. received their first permanent impression about sex from unwholesome sources.

The chief responsibility rests with the parents, many of whom know not where to turn for information. For such it can be said that lists of books are rapidly being made available through libraries, state boards of health and social hygiene societies. Here is where the crucial relation between father and son comes in. If they

have not been chums before this time, it is usually idle to try suddenly to gain the boy's confidence at this period. It is well to keep in mind, however, that some one will probably have his confidence and the best that the parent can do, if he does not have his child's confidence, is to see that he has wholesome friends.

This is one of the justifications for the Boy Scout movement and similar organizations in which the adolescent boy and girl have the advice of older boys and girls who have successfully passed this stage. For the present generation at least teachers must take an active part in this phase of education. The method that is proving to be most successful is individual instruction, the women taking the girls and the men the boys. Such instruction comes naturally for the biology teacher but the task is greater than he alone can undertake and in many schools biology is taught after sex instruction should have commenced.

It is also the best judgment of those who have had widest experience in sex instruction that all questions should be answered fully and frankly but that it is unwise to anticipate questions that will naturally arise as the child grows older. To discuss, for example, the question of prostitution with a boy of ten to twelve is an illustration of bad sex teaching. Information on prostitution naturally follows with the onset of adolescence.

In a similar manner, the problems arising out of the marriage state, belong to a later period of instruction. We have been too willing to believe that a general lecture on sex hygiene and a personal talk was all that was necessary. The problem is much more serious and its correct solution requires several years of instruction.

In any discussion of what not to do mention must be made of the diseases that arise from improper sex relations. The report comes from the Surgeon-General's office that of 200,000 cases of venereal disease in the Army during the European war, over 160,000 were brought in from civilian life. This indicates that there is a widespread laxity on the part of law-enforcing officials whose business it is to suppress the disease-spreading prostitute. It has been found as a result of many studies that prostitution flourishes only when city officials tolerate it and are complacent in their efforts to destroy it.

The problem of prostitution is becoming well understood and is best treated in an unbiased, scientific way. It has been shown through independent studies that the prostitutes of our country are largely young women who belong to the class of the feeble-minded. Some investigators place their estimate of the percentage of this class as high as 90 per cent. If the supply of available men is kept up, there must be a large number an-

nually recruited. The boys of high school age are the source of supply and it is the business of prostitutes to secure as many as possible.

All prostitutes sooner or later become diseased. Science has made us just as familiar with the two forms of venereal disease, gonorrhea and syphilis, as we are with diphtheria and pneumonia. It has proved conclusively that both of these diseases are communicable by contact and that their devastation is most serious.

With all of the elaborate care that nature has taken to produce normal germ cells, it is a sad pity that intelligent human beings should be the only forms of life that wilfully destroy them. When man descends to prostitution he becomes lower than animals, for through the diseases contracted, he may render his germ cells incapable of carrying on their work—the formation of a new human being.

Venereal disease, which is absent from animals, is the chief cause of sterility and the cause of more than 60 per cent. of all the operations upon the reproductive organs of women. The results of these diseases may be transmitted through several generations. The fathers have eaten sour grapes and the children's teeth are set on edge, is a figurative description of what happens. There is only one form of insanity for which a definite physical cause is certainly known, and this form of insanity

is due to syphilis. It is also well to remember that there is no cure for a human being rendered insane by this cause. Nearly all infant blindness is due to the infection of the eye of the child at birth with the germs of a venereal disease. There is nothing in the whole realm of knowledge that has such a cruel, persistent and far-reaching effect as venereal disease; and there are but few ways in which Biology has contributed more to the possibilities for human happiness and welfare than in its revelations in this regard.

It is wrong to assume that all cases of sterility are due to disease, for scientific studies have been made which clearly indicate that sterility is a relative term and that every degree and gradation between high fertility and complete sterility exist in both man and woman. This variable condition is due to incomplete development, autointoxication and other causes that the physician can usually correct.

It is very difficult to prescribe in a general way for this normal and natural activity of our bodies. Temperament and temptations are never exactly the same for two persons. Knowledge of the significance of the organs of generation and of the dangers from their abuse will not entirely protect nor prevent boys and girls from immorality. There must go with this necessary knowledge a

moral sense of right. The sexual desire is very strong in some people and their battle is a royal one. The first step in keeping clean is a correct understanding of what the parts of our bodies are and their inevitable activity for the greater part of our lives. The mere fact that all people possess reproductive organs, and yet a large number are not controlled by them, is one of the best arguments that they can be regulated by all. There is nothing physically impossible in the problem. Science and our present civilization unite in declaring that it is necessary that our bodies should be kept clean and strong in order that our children may not be handicapped in their efforts to live. One assumes a serious responsibility in taking a chance at blasting the life of his child of the future. Nature has set a big job for man in continuing the human race. The civilization of to-morrow is the product of to-day. The health of men who shall participate in this civilization of to-morrow is being decided to-day. One's moral responsibility for the health of future women should be enough to keep any sane man clean and pure. The knowledge that one's grandchildren may become insane or be born imbeciles as a result of his immorality is a moral obligation that cannot be shunned. It is a strange moral code that allows a young man to mortgage his future and the future

of his children and grandchildren. The question thus comes to a contest between selfish gratification and self-control; between weakness and strength; between immorality and morality.

CHAPTER VII

HEREDITY

In the two preceding chapters the law of biogenesis and its application to man were considered. One is impressed with the prodigality of Nature in the enormous waste of germ cells. This is a waste that progress in scientific knowledge is unable to lessen or to take advantage of. Chance is the only word that correctly describes which sperm cell shall unite with a given ovum; chance also is the word to use in regard to the maturing of ova preparatory to fertilization in all living things that reproduce sexually. In man not one in ten thousand of the ova nor one in one hundred thousand of the sperms participate in producing new human beings. Among other forms of life the death rate is even greater. The fundamental question of human progress is intimately linked with this chance union of sperm and ovum. Even our limited knowledge of their behavior enables us to predicate that there will always be a certain uniformity in the results. But within all of this uniformity, there exist sufficient possibilities for variation and for new combina-

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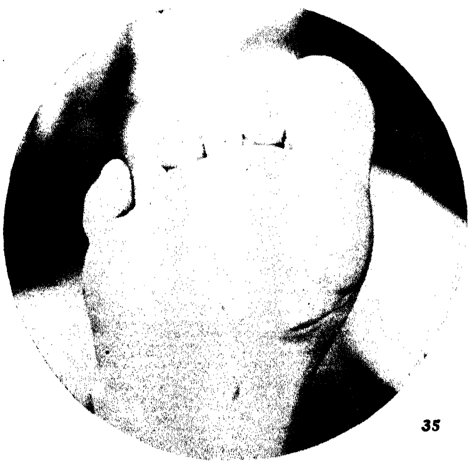

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FIGURE 34. Photograph of the feet of the infant daughter whose mother's foot is shown in Figure 35. The mother had six toes on each foot. This is an illustration of the kind of facts which are frequently associated with the term heredity. Photographs by Dr. C. L. Potter.

tions to explain the many differences which are common knowledge.

This aspect of the law of biogenesis fixes the characteristics of man with steel-like bands from which he never escapes. He may rise above them or sink because of them. They may become his most priceless heritage or his greatest affliction. They cannot be ignored in this age and when understood solve much that is fundamental in his educational problems.

Long before the beginning of the Christian era, thoughtful writers had recorded their observations in regard to some features of heredity. Their records deal largely with the morbid aspects, for we read, "I Jehovah, thy God, am a Jealous God, visiting the iniquity of the fathers upon the children, and upon the third and four generation of them that hate me." Deut. 10, 9.

This aspect of heredity, the morbid, became so firmly fixed in the minds of the masses of the people that not only malformations but diseases were believed to be inherited out of the past. There thus grew up a fatalistic feeling about many of these natural occurrences that was positively injurious to human welfare and the peace of mind of those afflicted. (Figs. 34-37.)

As we take up this imperfectly understood aspect of living protoplasm even to-day, a warning is necessary that we should keep constantly

in mind that the theoretical aspects of heredity are still in obscurity. It is an easy task to describe cells, to explain the nature and purpose of food or to designate the cause of the biological diseases, although much remains to be learned about these subjects, in comparison with a description of the problem of heredity. The uninformed write and speak freely concerning this illusive theme. The reader is asked to note carefully the places where the description of proved facts ceases and the discussion of theories about heredity begins.

Heredity is the name for one aspect of protoplasmic activity in the study of which we attempt to learn something of the history or inheritance of protoplasm. In this brief study we shall come to realize, the writer believes, that protoplasm is more than so many chemical elements having a certain pattern and physical appearance. It is a part of the past influencing the activities of the present.

Heredity must be thought of as a general term which is used to describe the repetition of parental characters in offspring, and so it is customary to say that the child inherits from its parents or that it has such and such a parental inheritance. The same terms are used in the transmission of property from parent to child, but there is this distinction, that the property is a material substance

FIGURE 36. An X-ray photograph of the feet of the daughter to see if she really did inherit the extra toes from her mother. In the left foot the bones of the fifth and sixth toes are double, while in the right foot this doubling extends only to the first two joints.

FIGURE 37. An X-ray photograph of the feet of the mother which shows that the doubling of the toes is not the same on each foot. A comparison of these conditions reveals that the daughter inherited the extra toe from her mother but that the doubling in the right foot is like the mother's left; and the doubling in the daughter's left is like the mother's right. Photographs by Dr. C. L. Potter.

such as land, money, or a house while biological inheritance in such a sense is a figure of speech.

Some term like heredity became necessary when spontaneous generation was scientifically proved to be untrue as an explanation for the origin of the varied forms of life. So long as man was content to believe that plants and animals might have a varied and independent origin, there was no difficulty in explaining the hereditary peculiarities of one of these groups. They simply had them when they were created and this precluded any possibility of tracing their origin. No explanation of heredity was possible.

Whatever may have been the pre-historic or early geologic history of life, the numerous forms of life including man have come into existence according to the law of biogenesis. This necessitates that we seek for the origin of all hereditary peculiarities in the ancestors of the forms of life that are being studied.

We will begin our discussion with a description of the present meaning of heredity. For this purpose the human hand may be considered. In Fig. 38 are shown three hands and there is no question about their being normal hands. Yet there are distinctive features about each. The hands on either end are the parents and the one in the middle the daughter. It is to be noted that the mother has a short little finger—about as

short as the first finger. The same peculiarity is seen in the hand of the daughter. She is thus said to inherit the length of her little finger from her mother. This character is clearly like that of one parent and not an intermediate length of finger between the short finger of the mother and the long one of the father.

The distance between the bases of the thumb and the first finger in the father's hand is proportionately much more than this same distance in the hand of the mother. The same distance in the hand of the daughter, who is eleven years old, is at least equal to that of her mother, and when she is mature, will be much greater. This characteristic she inherits from her father. There are a number of other peculiarities in the hand of the daughter that can be found in the hand of one or the other of her parents.

We thus come to recognize that the present-day meaning of heredity deals with the normal and natural form of the parts of our body as a similar comparison of other regions reveals. But one should recognize that the above description dealing with form and shape is but partially complete. It is equally instructive to make a comparison of physiological characters, for the quality of these processes is just as surely inherited as finger length. This aspect of heredity has been over-emphasized by popular writers who frequently assume the

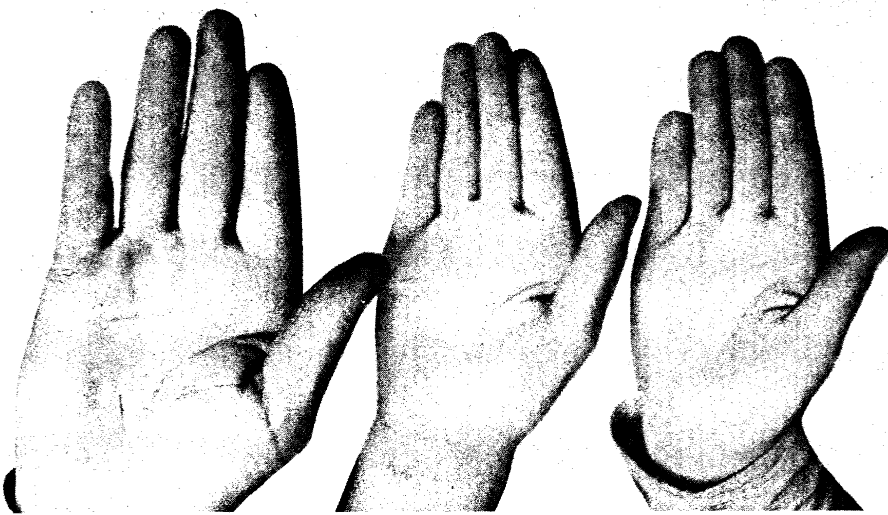

FIGURE 38. The hand at the left is of the father. The one at the right is the hand of the mother, while the one in the middle is the daughter's. See the text for further description of the interesting way in which this photograph illustrates heredity.

absence or presence of such traits as generosity, meanness, secretiveness, frankness and other qualities. It is necessary to warn against all such statements because these characteristics and many others are the common possession of mankind and all that heredity can be held responsible for is the *degree or intensity of such traits.* Heredity is thus the name under which are grouped the quality of the several traits of a man and not their absence or presence. Under this topic are assembled the influences of the past through the immediate and remote ancestors as they reach out of the past and lay a firm hand on the present.

Heredity is further to be distinguished from the congenital features which frequently occur. These are modifications which arise during the formation of the embryo such as birth-marks, hair-lip and similar deformities. Owing to the tendency to confuse "inherited" and "congenital," some prefer to substitute pathological for congenital, thus avoiding all possibility of misunderstanding.

In marked contrast to heredity stand the acquired modes of response which develop after the animal is born and begins reacting to its environment. These culminate in habits and are really secondary to the hereditary qualities. It is only a short time with the young animal or child before these two fields overlap and it soon becomes difficult to draw a sharp distinction between them.

They both contribute the raw materials out of which is constructed his intelligent reactions.

The modern students of heredity have thus fixed their attention upon structural and physiological characters and not upon their first origin. The origin of a hand, foot, ear, hair, feathers, brain or a four-parted heart are usually considered under the broader term of evolution.

Are there definite physical bodies which carry these numerous parental characters to the offspring? This important question has been answered in the chapter on The Law of Biogenesis. There it was shown that the chromatin during reproduction took on a specific form and was aggregated into definite masses that became known as chromosomes. (See page 76.) The chromosomes were shown to be equal in number in the male and female parents for all animals that reproduce sexually. To this generalization there is one exception upon which much emphasis is placed. For about this single fact is centered the modern explanation of sex. It has been observed by many critical students of cytoloty that during maturation an extra chromosome can be distinguished in part of the sperms. This extra chromosome is known as the sex-chromosome and is believed to contain the substance that produces femaleness. In so far as our technical studies

have revealed, the chromosomes are the only physical bodies which might be held responsible in transferring parental qualities to an offspring. Upon this point scientists are agreed: we accept as fact that the chromosomes are the physical bearers of heredity.

Their minute size alone makes this statement seem like a gross assumption, but there is no other material substance contributed by either parent by means of which traits could be transmitted. There is an enormous mass of technical papers dealing with the size, form and changes in chromosomes during fertilization which any interested reader may consult as the source of these facts. For those who do not wish to examine the original sources, it may be stated that chromatin grows and greatly increases in amount as each new cell is produced, thus carrying to this new cell the physical bodies which have through growth and division been derived from the parental chromosomes.

But when the next natural question is asked, How do these chromosomes carry characters from parent to offspring? we pass into the realm of hypothesis. Darwin offered the first hypothesis to explain heredity in 1868 and it is always well for the student who wishes to understand the various views that have been advanced to begin his

study by reading Darwin's hypothesis of pangenesis. In the large treatises on heredity will be found theories by Spencer, Altman, Weismann, Naegeli, Galton, Roux, Driesch, Bateson, Mendel and numerous writers of to-day, among whom Castle, Morgan, Jennings, Davenport and Pearl are the best known, and they should all be read in connection with the question of how the chromosomes transmit parental characters.

In the illustrations accompanying this chapter, it is to be noted that the complete transference of parental characters to offspring does not occur. There is always a distiguishable difference. We use the term variation in biology to describe the differences of structure, of instincts or of elements which occur between the offspring and parent.

If there were complete transference of hereditary characters, then the offspring would be identical with the parent and there would never have been any progressive development in animals and plants.

The amount of variation that can take place in a structure without changing the character of the object is hardly appreciated until one makes a critical study of the parts of living things. In Fig. 39 is shown the range of variation in the length and form of the heads of wheat. All of

FIGURE 39. Variation in the size and shape of the heads of wheat in nature. Scientists are studying the conditions under which the larger heads can be grown. (Photograph furnished by Depart. Plant Breeding, Cornell Univ.)

these heads of wheat are of the same kind and collected from the same field. They were grown under similar conditions. To a certain extent some of these variations are inheritable as the facts in Fig. 40 indicate. Given the same amount of timothy seed and planted under as nearly identical conditions as it is possible for man to control, the variation in the size of the bundles of timothy indicates that more timothy is grown from seed selected from plants that were large and bore long heads. These facts are of great importance to man in his constant efforts to improve his crops and domestic animals. (Figs. 39-40.)

At first thought it would seem as if man held the key to unlock one of Nature's secrets. But the limit in the amount of change that can be produced is soon reached and the trotting horse that has established a record may beget offspring that will never equal his record. The next time that the trotting record is broken, it is by a horse with a different heredity than the one that last made the record.

Every now and then there seems to be a chance combination of qualities in an offspring which enables the possessor to excel. Sometimes such an individual is able to hand these same qualities on for a number of generations, thus producing no new varieties. In all of these studies of variation,

it is found that there is a rather fixed limit beyond which each species does not vary. This limit is not the same for all living things, being restricted to minute changes in some and permitting marked modifications in others.

The ideas advanced by Mendel come nearer to explaining this difficult phase of our subject than the hypothesis of any one else, although it should be said that the modern interpretations of Mendel have carried his views much farther than when he first formulated them.

Johann Gregor Mendel, a monk of the monastery of Brünn in Austria, spent eight years experimenting in his gardens with varieties of edible peas. He carried on this work as a side issue and for recreation. Up to the time that his observations were published in 1866, all writers upon heredity had regarded the individual plant or animal as a unit. This meant that the hand characters shown in Fig. 38 as well as all others were bound up in an individual and could not be sorted out. This important conception is made clearer in the following experiment of Mendel's:

He selected an edible pea that normally grew six or seven feet tall and one that had a stem of from one-half a foot to a foot and a half. When these two varieties of peas were crossed (i.e., the pollen of the short variety was placed on the stigma of the tall variety or vice versa) the off-

spring of this cross were all tall, some of them taller than the tall parent. This generation produced from the cross is known as the first hybrid generation. When the seed of this hybrid generation is planted, the plants are partly tall and partly short, but none is intermediate. Tallness and shortness are distinct characters. In the subsequent breeding of this experiment the short peas gave rise to short peas and the tall ones to tall peas. Because tallness occurred in all of the offspring of the first hybrid generation, it is said to be dominant over shortness. On the other hand, short peas occurred in the second hybrid generation and this character of shortness is said to be recessive to tallness. When any such cross is made, the peas are either tall or short so that these two characters are in opposition. The one that occurs must have prevented the other from acting and it thus remains dormant. This factor of tallness and shortness is a character that passes entirely to the offspring and is thus known as a unit character. In order that unit characters shall reappear in offspring, they must be represented previously by what is commonly called the genes or determiners in one or both sex cells. These genes are believed to keep their identity and are passed on into the newly formed sex cells in each individual. All of the genes are located in the chromosomes and apparently have the power

of growth. They do not migrate into the germ cells from all parts of the body.

There is no question about the facts of heredity and that the parental characters reappear in the offspring as unit characters and that one character usually is so prominent that it completely obscures or prevents the weaker from appearing. But as soon as we pass over into an explanation of how unit characters are transmitted or why they frequently are united in pairs, i.e., the tall pea might have yellow seeds and the short pea green seeds and the two characters, length of stem and color of seed, be transmitted together, we pass into the theoretical. Various hypotheses have been formulated about heredity. Such a proceeding is necessary in order that the experimenters may have a definite problem to solve. They either confirm or disprove the hypothesis. The fact that many hypotheses of science have been discarded is taken by those who do not understand the scientific method as an evidence of weakness, when it is really only the method of procedure. The real difficulty arises in the masses of people trying to accept the various working hypotheses of science as final explanations. We shall have many more hypotheses about heredity as we become more skilled in analyzing this phase of living protoplasm.

FIGURE 40. The five bundles of timothy shown in this picture were grown from the same amount of seed under identical conditions. This is a variation in the quantity of hay that can be grown from the same amount of seed. It is, therefore, valuable that good seed be planted. (Photograph furnished by Depart. Plant Breeding, Cornell Univ.)

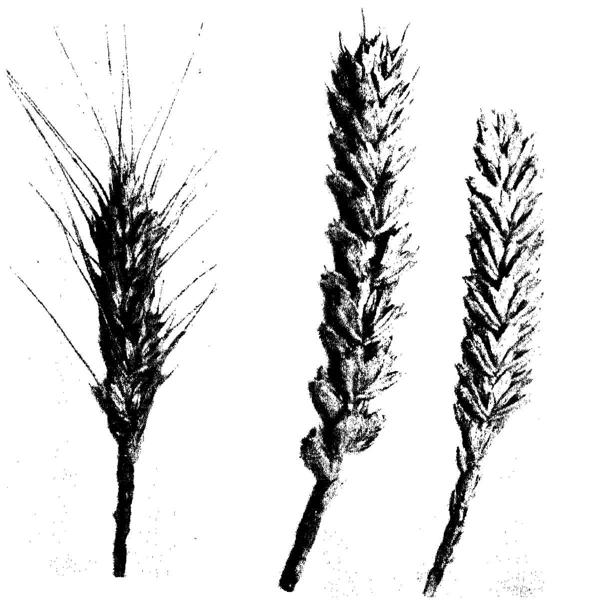

FIGURE 41. Photograph to show the effect of crossing one variety of wheat with another. The large head in the middle is the result of this crossing. See text for further details. (Photograph furnished Depart. Plant Breeding, Cornell Univ.)

In recent years attention has been focused upon the idea of selecting certain unit characters in parents and perpetuating them. Animal and plant breeders have been making extensive experiments, selecting first one then another specific character that they wished to have in the offspring Fig. 41 shows how this is done. Desiring to eliminate the bearded nature of wheat, a cross is made with a variety that is not bearded and is at the same time dominant over beardedness. In a similar manner a larger yield of milk or berries can be secured, although, as stated above, there is an upper limit beyond which one cannot force an organism.

For many years more attention has been given to the rearing of animals and plants than to the rearing of human beings. Man is no exception to the rest of living things in his inheritance. The art of being well-born or "eugenics" is the study of heredity as it applies to man. This study has yielded some astonishing results which should become better known. In order to give the reader access to some of these facts in more detail a few of the more important books dealing with eugenics are listed at the close of this chapter.

It seems that industry, shiftlessness, morality, immorality, integrity, moral obliquity and similar traits, as well as some forms of imbecility, are

human characters that are in part inheritable. This has led thinkers along this line to advocate certain restrictions for the physically unfit which raises such a question as the following: Is it right for an imbecile to beget children when we know that imbecility is inherited as a unit character and is usually dominant even if but one parent suffers from this malady? In some states laws have been passed prohibiting the marriage of mental defectives.

If all of these traits are inherited, then the characteristics upon which character is built are heritable. This leaves to man the problem of training, developing and unfolding but not of creating characteristics. Man possesses a comparatively simple digestive system which we have found to exhibit a low degree of efficiency. On the other hand, he has a remarkably specialized nervous system which enables him not only to control his own physical destiny but also his environment. Both of these organs are heritable qualities in man and always will be. The inheritance of normal man is limited in that he is never very tall or very short—other characteristics are similarly restricted. There is no record of marked change in historic time in the physical and mental traits of mankind. There will always continue to be chance combinations of genes as the chromosomes fuse in fertilization that

will result in specially gifted human beings, but there is no scientific basis for the belief that they will always beget equally gifted children.

This brings us to ask the question, Is there to be further human progress? In so far as man's body is concerned, it long ago became limited and never has overstepped these barriers. There is no reason to expect that it ever will. Conklin calls attention to the marked restrictions that exist in all forms of life in the following: "Among animals no new phyla have appeared since the vertebrates in the Silurian or perhaps even earlier; no new classes since mammals in the Triassic and birds in the Jurassic. In the evolution of animals only about fourteen times in the whole history of life have new phyletic paths been found and several of these were blind alleys that led nowhere. The climax of the progressive evolution of fishes was probably reached in the Devonian, of amphibians in the Permian, of reptiles in the Mesozoic. In all these classes the formation of new species has been going on more or less continuously, but progressive evolution in the sense of increasing complexity or organization has reached or passed its climax." It would seem, then, that man's progress was restricted to intellectual activities the discussion of which will constitute the main theme of chapters IX and X.

References

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CHAPTER VIII

SOME APPLICATIONS OF THE LAWS OF PROTOPLASM

THERE is no authentic record of the time when disease first laid its palsied hand on living things. The vast remains of organisms found massed as fossils in numerous rock outcroppings suggest that destructive epidemics have been common ever since life began. After all of the prodigality of Nature in insuring that life shall be perpetuated, it seems strange that the inter-relationships of organisms should have taken on such fatal consequences. The cause of all the greatest catastrophies, whether geologic or modern, has not been a physical manifestation, such as a volcanic eruption or poisoning due to the escape of noxious gases from the cavernous depths of the earth, but in the main has been due to the action of microscopic plants and animals living as parasites. In this dependent relationship, they cause disease and death.

Human effort to prolong life has ever stimulated man to try to understand the causes of death. If one measures his interest by the financial standard, he has come to have an intense desire not only to know more about this phase of protoplas-

mic activity but also he believes that his efforts have met with a large measure of success. For in 1917 (the most recent year for which figures are available) he agreed to use $120,000,000 for the general purpose of safeguarding and promoting public health in the United States alone in cities having 30,000 or more inhabitants.

This is a vast sum of money to be appropriated from the taxes and one needs to be warned that all of these preventive measures do not necessarily insure protection. We lull ourselves into a false sense of security when we accept such measures as wholly adequate. In the last analysis disease and death are both largely dependent on the inherited constitution of the body and the state of health at the time that it is exposed to disease-causing germs. Public health measures will never supplant these fundamental principles and the American people are in danger of being educated away from the significance of the elementary laws of living protoplasm and the limits under which they can be modified.

That we are still far from understanding the causes of death, a study of the epidemic of influenza in 1918-19 reveals. The term pandemic better describes its extensiveness, for it was world-wide and of greater severity than any previous outbreaks. This means that nearly the entire

human race was exposed to the germs that caused this disease. The mortality results were by no means uniform. In some cities the mortality was very high at the beginning and gradually receded. But this was not at all uniform. The duration of the epidemic was very variable. These and other important conclusions deduced from a compilation of a large number of statistics indicate that there was no correlation between mortality and the various repressive measures such as prevention of public gatherings, compulsory wearing of masks, etc. It has become plainly evident that the usual public health measures do not explain why the inhabitants of one city showed a low mortality rate and a quick recovery while a neighboring city had an entirely different experience.

Upon this point one eminent authority writes as follows: "The conclusion stands near at hand, not proven but strongly indicated by the evidence now available, that the primary factor in causing the observed variation between different communities, in respect of reaction to the influenza epidemic, was the biologic constitution or organic fitness of the people making up the population of these communities. Communities in some degrees organically unsound, as indicated by relatively high normal death rates from phthisis, organic heart disease, and nephritis, were less able to meet suc-

cessfully the attack of a vicious epidemic invader than were those in which these biologic conditions did not exist." Pearl.

It would be a mistake to infer that public health measures are not beneficial, for it is common knowledge that improvement in sanitary conditions has been helpful in reducing the death rate in tuberculosis, typhoid, yellow fever and malaria. The reduction of the death rate in diphtheria is due rather to curative methods than to sanitary reform. During the war the Red Cross made extensive observations on the prevention of diseases in France, Italy, Siberia, Greece, Bulgaria and other countries and it was found that there was a marked increase in tuberculosis, malaria, typhoid and similar maladies. Here the increase appears to be due to the privations and hardships of war. This is one of those dramatic illustrations which shows the beneficial results of good sanitation.

He who is interested in the prolongation of human life must understand the present-day evidence of science concerning the agencies that cause contagious diseases. Here are to be found a mass of proven facts that not only command our intellectual recognition but also have come to be recognized as having a legal force. As soon as one comprehends the bearing of such facts, his attention is turned to their application and the employment of all agencies that make for human

betterment. Some of these are experiments which will prove to be a failure, while others will be of great value. One should keep an open mind toward all public health movements for they furnish the sole means for human betterment so far as good health is concerned. As valuable as all such measures are, they can never deal with the inherited constitution of man nor give to him that natural immunity which is his most valuable possession as a protection against disease. Let us first examine the contribution that science has made in analyzing the causes of disease and later discuss some of the methods employed for human betterment.

Disease is a broad and ill-defined term. While it may be applied to sickness arising from drugs or mechanical injury, it is restricted in this discussion to derangements caused by specific organisms.

That man may be sick is granted by nearly all, but the extent of sickness is realized by only a few. A recent report on the conservation of national vitality estimates that there are always 3,000,000 sick persons in the United States of whom 1,000,000 are in the working period of life. These persons are estimated to lose in earnings $5,000,000 per year. To this must be added the expense for medicines, special foods, etc. The conclusion of the whole matter is that there is an estimated

loss of more than one and a half billions of dollars annually from sickness in the United States, one half of which is preventable.

It is a matter of history that more men died from sickness in the Spanish-American war than from bullets. In the recent great war, it has been repeatedly stated that both the Allies and Central Powers have had more men unfit for service from sickness than from injuries, and influenza killed more civilians that both wounds and sickness in the armies.

The quarantine laws passed not only by our nation but by the nations of the world indicate that there is a very general belief that man may be sick and that he may give this same sickness to other men. The further carrying out of the quarantine regulations so that they apply to states, countries, cities and finally to a single house where a person is sick, is but the logical application of our national quarantine regulations. These preventive measures are so important that they have been put under the police power and not under civil administration where they might be modified by political manipulation. The laws which the free people of the United States have allowed to be imposed upon them in regard to the preventable sicknesses are among the most drastic to be found anywhere in the world. This would seem to in-

dicate that civilized man has come to regard disease as having a very direct and important relation to life.

"But," we are frequently asked, "do the rest of living beings become sick and die before they reach old age?" The facts bearing upon this subject are not as well known as those just stated in regard to man. The expert upon animals in the Department of Agriculture estimates that the annual loss from disease in cattle, sheep and hogs is $212,000,000. A second expert in economic entomology in the same department estimates the annual loss, by insects alone, to the timber in the forests of the United States as $62,500,000. During the past ten years the Gypsy moth has spread over the New England states and has left them almost treeless in some places. Just now the white-pine blister rust is beginning to destroy the pines in several of the eastern states. We dare not predict how serious this disease may become. The potato blight, the damage done to the cereal plants, the injury to fruits, each tells the same story.

All the plants and animals just enumerated are of industrial importance but some one may also ask if the unimportant plants and animals are never sick. It does not make any difference where one looks in nature, there he can find organisms

that are subject to disease. The unicellular forms of life become sick and die in unnumbered thousands. Grasshoppers have been noticed to die in great numbers and frequently some epidemic attacks all of the fish in a lake or pond and the shores become littered with their dead bodies.

More facts might be marshaled but enough have been stated to warrant the conclusion that disease is of common occurence in all forms of life and that man thus forms no exception. Some of the recent paleontological investigations reveal that animals were subject to parasites, and hence disease, in the age of molluscs and fishes. (Figs. 42-43.)

In order to make this study of disease reveal something of the fundamental nature of life, we must inquire into a few of its details.

It makes but little difference where one begins his study, in what group of plants or of animals. Take the common dandelion which many of us regard as a weed and a pest in the lawns. It is generally distributed in open lots and along the sidewalks in the uncared-for parts of most cities. The typical and normal plant has a round flower stalk and a symmetrical blossom. If one examines more closely the flowers of a number of speciments, there will be found some with a wide, flat flower stalk supporting an irregular over-

FIGURE 42. Ancient diseased fossil bone. The bone tumor shown in this photograph is the oldest hemangioma known. These vertebrae belong far back in the tail of a Brontosaurus known as Apatosaurus. The growth of this tumor has destroyed all evidences of the articular surface. The photograph is one-quarter natural size. The fossil is from the Como Beds, Comanchian, Wyoming. Furnished by and published with the permission of Roy L. Moodie.

FIGURE 43. A similar bone tumor. Taken with an X-ray photographic machine, the two diseases are similar. Dr. C. L. Potter.

grown flower. The width of a flower and its stalk is frequently from three to five times greater than that of a normal blossom and stalk. When these conditions were first studied, they were interpreted as normal variations; but further observations indicated that the soil was too rich and that these plants had been overeating of the good things in a dandelion's life with the result that abnormal giant flowers were produced. No one so far as I know has attempted to work out the exact chemical stimulus that is responsible for this excessive growth, but the writer is inclined to think that we may say that these dandelions with abnormal flowers are diseased. Every spring in New York state there blossoms an early flower, the spring-beauty (Claytonia Virginica) and frequently brownish blotches are found on the leaves. As the blotches spread the leaf curls up, and, if several leaves are attacked, the dainty flowers wither before the seeds have ripened. The blotches are due to the growth of one of the leaf moulds, the hyphæ of which have penetrated into the mesophyll of the leaf. Here they absorb the nourishment which should go to the leaf. If the mould is successful, its reproductive elements ripen and spread to other plants. If the spring-beauty is successful in resisting the attack, the seeds mature. The spring-beauty having these brown

blotches on its leaves is diseased. The mould that is living at the expense of the spring-beauty is termed a parasite.

Now consider the adult honey bees in this country which suffer from two diseases—paralysis and dysentery. Dysentery in one form is infectious and due to the presence of a protozoan in the mid-gut region of the intestinal canal. This portion of the intestine in diseased bees, which die of a virulent form of dysentery, is found to be milk-white and completely filled with spores. These protozoan spores are present in the excrement, on the frames and walls of the hive.

But the most serious losses to the bee-keepers come from a disease which occurs in the larvæ and is known as the American foul brood. "The brood affected with this disease is usually capped before it dies. The color of the dead brood presents in general various shades of brown. The marked ropiness of the decaying remains of the dead larvæ is probably the most characteristic and well-known feature of the disease." Here in these insects exist diseases that follow a regular sequence, as in higher animals and plants. The course in American foul brood is due to a specific germ which can now be properly prevented.

The two specific illustrations just described demonstrate that a definite plant or animal is

found when the symptoms of these germ diseases are present. Man alone is subject to about one hundred such diseases, while the number affecting plants and animals as a whole must be many thousands. In each one of the diseases caused by specific organisms there are equally specific symptoms each of which requires definite treatment. This is the reason why patent medicines misrepresent their claims. Each patent medicine might be helpful to a single disease but it is utterly impossible to conceive how it can have any remedial influence for the many diseases usually specified.

When science established the fact that definite organisms were associated with specific diseases, one of the greatest discoveries in medicine was made. Since this point of view has been the dominant one notable progress has been possible. But the mere presence of these organisms does not explain how they cause disease nor how an organism recovers. Neither of these problems is satisfactorily solved in all biological diseases, although great progress has been made, but we can illustrate in some cases how disease is caused.

The poisonous rattlesnakes are well known to cause death as a result of biting man and animals. In the head of the rattlesnake is found a large salivary gland which is now devoted to the pro-

duction of poison. The duct (Fig. 44) from this gland opens into the base of a hollow tooth. When the rattlesnake strikes its victim, the jaws are thrown back and the whole head moves forward toward its victim. The teeth on the upper jaw penetrate the skin. As the head is withdrawn, the muscles over the body of the gland

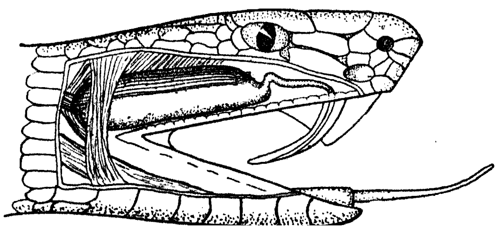


FIGURE 44. Diagram of the head of a rattlesnake. The skin and part of the muscles have been removed. The long oval mass in the upper jaw which is connected by a tube with the curved tooth, the poison fang, is the poison sac or gland. This is a modified salivary gland. There is an oval pit just below the round nostril opening which is present in poisonous snakes only.

press on the gland and thus help to force the poison into the victim.

The following shows what actually happens after this poison enters the blood of man: One of the attendants at the National Zoological Park was bitten, on August 17, on the middle finger of the left hand. The wound was immediately sucked and within fifteen minutes cauterized with a 1 per cent. solution of potassium permanganate.

He was removed to a hospital where the following changes were noted: On admission his blood was examined and found to give the following counts: red blood corpuscles, 4,600,000; white blood corpuscles, 14,440; with the hemoglobin of the blood testing 95 per cent. Eighteen hours after being bitten, the blood was again examined and the following changes were seen to have taken place: red blood corpuscles, 4,000,000; white blood, 16,000, hemoglobin reduced to 75 per cent. On the fourth day the blood count showed the following: red blood corpuscles reduced to 2,800,000; white blood corpuscles, 14,000, and the hemoglobin of the blood now 60 per cent. On the sixth day there were but 2,000,000 red blood corpuscles, 12,000 white corpuscles and the hemoglobin at but 45 per cent. The patient recovered but it was more than six weeks before his blood became normal.

In this study we can see definite changes taking place following the introduction of the poison from the rattlesnake into the blood. The most noticeable is the great destruction of red blood corpuscles followed by the loss of the hemoglobin content of the blood. The hemoglobin is located in the red corpuscles and has the special work of carrying oxygen from the lungs to all parts of the body. If enough red corpuscles are destroyed by this snake poison, the cells of the body die because they are not adequately supplied with oxy-

gen. While this is the most conspicuous aspect of this disease caused by the poison of the rattlesnake, it is only a part of the story. The main point to be emphasized in this connection is that a definite poison introduced into the blood produced specific results.

The question is often raised why it is safe to suck the wound and swallow the poison thus removed. The explanation is very simple. The poison of the rattlesnake is made up of a substance known as protein, similar to the protein of our food. When a protein is taken into the stomach, it is digested and this is what happens to the poison of the rattlesnake. If the white of a hen's egg is injected directly into the blood of man, it acts as a violent poison, although when taken into the stomach it is one of the best of foods.

The following illustration presents a similar phase of the problem—how organisms cause disease: There is one group of plants known by the general term of Fungi. To this group belong bread mould, bacteria, and mushrooms. The common application of the name toadstool or mushroom has no scientific meaning. The plants to which these general terms are applied have specific scientific names which enable the expert to recognize them. There are no common tests by means of which those that are poisonous and those that are not can be distinguished. It is necessary

to know the kinds of toadstools that are harmless before eating them.

One of the mushrooms that causes many deaths annually belongs to the Amanita group of fungi. It produces a substance that is not destroyed by the heat of cooking nor is it modified by the action of digestive juices. So when these plants are eaten, the poison passes into the blood where it usually causes death after producing a well known series of changes. (Fig. 45.)

The poison grown in the salivary gland of a rattlesnake and the Amanita poison grown in the cells of this mushroom are both natural products of these organisms. Scientists have decided to call the product of the salivary gland of the rattlesnake a poison, while the poison manufactured by the Amanita is dubbed a toxine.

When bacteria live in the body of animals as parasites, they frequently cause disease as shown for bees, and as is well known in the diseases of diphtheria, tuberculosis, bubonic plague, etc., common to man. It has been shown that there is produced as a result of their living in such relations to another living body certain waste products to which the term toxine as defined above has been applied. These toxine products are believed to be the main cause of the disease which follows after the bacteria have been living for a certain length of time in the body. (Fig. 46.)

The bacteria or germs which cause many of the common diseases in man and animals are abundant in nature and commonly found where man lives. An examination of any group of men will usually show the presence of many of the commoner bacteria in the body although none of the men thus examined may be suffering from any disease. This leads to the second inquiry, How does man recover from a disease and why is he not sick all of the time if he harbors disease producing bacteria?

Recovery and the resistance to disease exhibited by living things introduce us to one of the most distinctive phases of living protoplasm. Disease has been known from remote times and yet numerous plants, animals and men inhabit the globe. These have survived the ravages of disease or have never succumbed to their poisons. It it well known that there is a natural resistance to disease which is held unequally by man and animals and plants; some men are never sick and others seem to be unable to resist any form of disease. Again the powers of resistance are higher under certain conditions than others. This power to resist the organisms that invade the body is called immunity. It is one of the fundamental characteristics of all living things. Immunity has two general aspects: resistance to the microörganisms themselves and resistance to the microbial poisons or toxines.

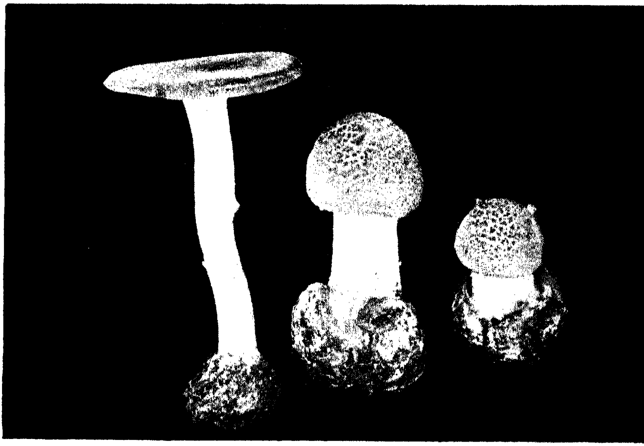


FIGURE 45. The fungus known as Amanita which produces as a natural growth product one of the most deadly poisons. Published by permission of the New York State College of Forestry.

Were the space available to review the conditions that are known to exist in the simpler animals and plants it would be easy to show that there is a large amount of natural resistance in both of these aspects of immunity. But these two do not always exist to the same extent in the same animal, as the following illustrates: It is well known that sheep are the most susceptible of all the mammals to the toxine produced by the germs of the tubercle bacilli, while the guinea-pig is very slightly susceptible; but the guinea-pig is very susceptible to the tubercle bacilli themselves while the sheep is very resistant. Such examples as these warrant the distinction just made that immunity to the poison and to the germs are two distinct things.

Given this natural immunity, which is found to be generally distributed among all forms of life, how does it happen that there is any sickness? It is not easy to answer this question in such an outline treatment as is given in this book, but it may be suggested that to overcome resistance, the germs must be virulent and the host receptive. We are unable to state just what the conditions are that make the host receptive to germs or how to eliminate the condition. Under certain conditions and after a given length of time the symptoms of a definite disease appear in the body.

These symptoms run their course and the body

recovers. The study of the conditions of recovery give us still further insight into this phase of living protoplasm. It is common observation that human beings do recover from measles, typhoid fever, diphtheria and other germ diseases. Very little idea of how this recovery was brought about existed until after Jenner, in 1789, attempted to imitate nature and artificially produce an immunity to certain diseases. Acting upon the principles discovered by Jenner and others, we have to-day more than a dozen antitoxines. If it were possible to remove the germs which cause any given disease from the body, the elaborate experimentation which has been carried on to discover suitable antitoxines would be unnecessary. The underlying principle in the use of antitoxines (and there must be a specific one for each disease because the toxines produced by each different germ are distinct) is gradually to accustom the cells of the body to the poison in a mild form so that during the process these same cells will elaborate antibodies for the particular poison introduced into the body.

It is now possible to produce these antibodies in animals other than man, extract them from their blood and preserve them for subsequent use in man when he happens to be suffering from diphtheria, for example. Such antibodies are called antitoxines. An antitoxine when introduced

into the blood of man helps to neutralize the poison which the germs have set free into the blood. If the body is able to recover from this disease without the use of antitoxine, it is believed that it has been able to manufacture its own antitoxine. That this is probably the correct interpretation, the study of "carriers" seems to prove.

After a person recovers from diphtheria and is able to go about his usual duties, he may have a number of active diphtheria germs in the nasal passages or throat. In sneezing or coughing, these are set free in the air. If they find lodgment in the nose or throat of another, they may cause him to have diphtheria. The first man has become immune to the poisons which now cause the second man to have diphtheria. Diphtheria epidemics in schools are frequently caused by the germs being discharged from an apparently well child.

In the case of several diseases, the body is immune from subsequent attacks. In a figurative sense, we might say that the cell remembered the struggle that it had to throw off the poison and prepared defenses against a second attack. But not all people are protected from a second attack of whooping cough, for example, nor are those who are immune at one time necessarily immune for all time. The general condition of the body has a large influence upon man's ability to resist disease. Is he well nourished? Are the muscles

regularly exercised? Is the mind occupied and contented? Such factors have a large influence in enabling man to resist the poisons given off by germs after they gain access to the body.

In the illustration given of diphtheria, it was shown that man might become accustomed to these poisonous products and that his cells probably produced a neutralizing antitoxine. In other words, the body adjusted itself to a new or unusual condition. This is a relation which living protoplasm is able to undertake, wherever living protoplasm is found. It is everywhere apparent in nature. Fig. 47 shows a spruce tree which has tipped partly over, due to the undermining influence of the high water. The tip of the tree has adapted itself to this new position. Two of the limbs have become tree-like in their symmetry and bear cones. This is an adaptation taking place in nature in which part of the tree underwent a radical modification in attempting to adjust itself to new conditions. This is especially noticeable in the tree-like symmetry of the two limbs—a condition never seen while the tree stands in an upright position.

In this discussion of the scientific principles connected with diseases caused by animals and plants, a few generalizations have become clearly defined:

1. Theoretically all of them are preventable.

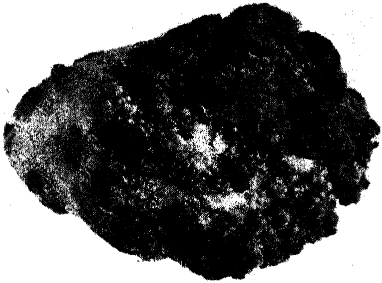


FIGURE 46. A sick potato that has a disease, the potato wart, which not only renders the potato unfit for food but which will also destroy it. Bureau Plant Industry.

FIGURE 47. Photograph of a spruce tree, the roots of which have been partly undermined by the water. As a result the tree blew over but was not entirely freed from the soil. As it continued to live in this unusual position, the tip of the trunk turned upwards and two of the limbs became tree-like in their symmetry. Some idea of the extent of the adaptation is gained by comparing the unchanged limbs with the two that look like young trees. This experiment took place in nature uninfluenced by man.

2. All living things may recover from every form of germ disease to which they are subject—none is necessarily fatal.

3. The occurrence of these diseases is the cause of great economic waste.

Our study of reproduction and heredity revealed that there will always be a large measure of chance in the formation of a new human being. This will always result in the production of some who are constitutionally weak, some who are very strong and many that will fall in between these limits. When the constitutionally weak become infected with germ diseases, they will probably succumb, irrespective of sanitary conditions and hygienic living.

Public health regulations aim to destroy all unsanitary living conditions, 1, because the general health of the individual has been proved to be lower when living in such a state; and, 2, because many forms of germs thrive best where filth is most abundant. An important fact to be remembered, however, is that some of the disease germs do not thrive outside of the human body. These regulations have the further aim to see that man's food is kept clean and that those harboring disease germs are prevented from passing them on to others. The broadening of his activity to compass general hygienic and healthful exercises is an

attempt to help man to make the best fight possible—a fight which he alone has to make when it comes to the final analysis.

The reason, then, that we give so freely to public health measures is that it is the only way known by which man can be assisted. It is a well-recognized feature of all of this work that by helping the body to keep well nourished and in a generally good state of health its resistance to the poisons of germs is increased—often to the point where it is completely able to throw off the offending germs. To help man to help himself and to enable him to live in better health and longer is in itself a sufficient stimulus for all of this work that is being carried on. As was suggested at the beginning of this review, it is important to keep in mind that all of these regulations, based on the latest and best findings of science, cannot go beyond certain limits. They cannot furnish man with a different immunity than Nature gave him at birth. They must always apply within the range of variation for human beings. They cannot create any superman who shall have unheard-of ability in resisting disease. It is very much to be doubted if the general immunity of mankind will improve as more and more men come to live in crowded cities and work within doors. We should expect the reverse to become true as the

development of rugged constitutions requires vigorous exercise and plenty of fresh air.

The correct valuing of the contributions of science toward disease and a proper recognition of the limits within which all public health regulations apply will save mankind many millions of dollars annually which are now spent on patent medicines and quack doctors. To speak of the American people as intelligent when so many health fakers can exist is an abuse of the term. The future holds much in promise for those who clearly comprehend the working of the basal laws of reproduction and heredity and their relation to good health.

CHAPTER IX

THE LAW OF SENSATION AND THE NERVOUS SYSTEM OF MAN

THE dominance of the mind of man and its outstanding significance in his life make it difficult for us to analyze it in relation to the other basal laws of protoplasm. The human mind is able to take advantage of all discoveries of all past epochs. Such vast powers overshadow the more elemental features and obscure the relations which the mind of man bears to animals.

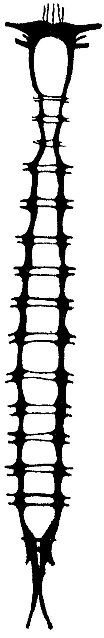
The law of sensation deals with the several structures that are modified to respond to stimuli and the reactions which they incite. The fundamental features of this problem are the same in all animals. Man gains his information in just the same manner as the other higher animals and through the same avenues. There is nothing unique or peculiar about man. By means of this law all animals regulate their several organ systems and adjust themselves to their environment.

This feature of protoplasm is nevertheless governed by laws and acts within prescribed

limits in a manner similar to the processes of reproduction or metabolism. The method followed in this book should not make one lose sight of the fact that none of these basal laws acts independently. They are inextricably bound up in a living organism which is the unit. Each law has no significance apart from this relationship—all are necessary to form life.

What are the several aspects of this primary law of protoplasm and the bearing of the more recent discoveries? Does this form of analysis help one to gain a better understanding of his own mental processes? The current views concerning the organization of the structures through which this phase of vital activity takes place enable us to gain a new picture of its probable method of working. Some of the prominent popular hypotheses will find no place in this discussion because they have really been supplanted. Unfortunately the complexity of the nervous system is such that it requires a certain amount of technical description before one can properly appreciate the significance of the generalizations that science has made. Those who resent this form of analysis should remember that mind and body are intimately associated.

The simple animal cell, the ameba described on page 36, is able to eat, carry on the processes of metabolism, respiration, excretion and repro-



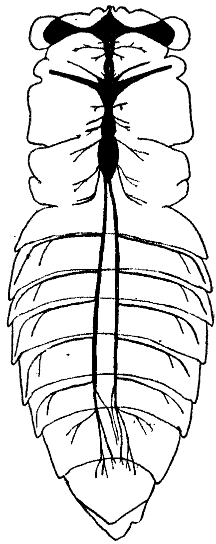


FIGURE 48. The entire central nervous system of one of the shrimps (Branchipus venales), magnified ten times. Redrawn from Hilton. There is a tendency toward a slight concentration of nervous tissue at the anterior end which is called the brain. In applying the term brain to this nervous mass, there is no thought of suggesting that it is similar to the brain shown in Figure 49.

FIGURE 49. The central nervous system and many of the nerves of the seventeen-year locust. The nerve ganglia have migrated toward the anterior end of the animal's body until the posterior half contains nerves only. These two illustrations show in a striking fashion the concentration of nervous tissue into a brain.

duction. This minute bit of protoplasm is adapted to its environment and responds to light, chemical and mechanical stimuli. Here are found the elementary characteristics of the law of sensation. No specific structures are differentiated for special stimuli, or for conducting the effect of such stimuli or for reflex action. But rather the entire protoplasm participates in these processes just as it does in reproduction or metabolism.

But just as soon as one comes to examine the more complex animals, like the worms or crabs, different kinds of tissues and organs are the first things to be noted. Extending throughout the length of the body of such animals is found a chain of ganglia connected by strands of nerve fibers. (Figs. 48-49.) These ganglia are composed of nerve cells that either send their fibers to the muscles or from ganglia to ganglia. In the skin and special sense organs of these same animals are found several kinds of cells that are differentiated to respond to environmental stimuli. Through these nerve cells, the receptors, the animal is able to appreciate certain changes. All of the tissues and organs of such animals are regulated by these nerve cells. When the nerve cells are thus organized and occupy such a definite position in the body, one is able to say that the worm has a central nervous system.

In all of the vertebrates, the central nervous

system is closely organized and specialized into a brain and spinal cord. Here are found the same motor cells connected with the muscles and veins of the body and numerous nerve cells that serve to connect the different parts of the central nervous system. This latter class of cells is always located entirely within the central nervous system. Part of the sensory nerve cells of vertebrates remain on the surface of the body as the

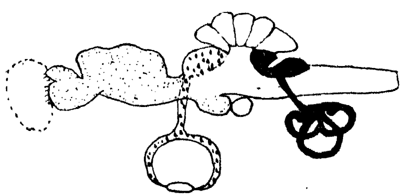


FIGURE 50. Diagram of the brain of a dogfish. The "nose brain" is shown with small dots; the "eye brain" in coarse dots and the "ear brain" in solid black.

eyes, taste, smell and hearing; and part of them have taken up a position deep within the body, but they send nerve fibers to the surface as in touch, cold or hot receptors. There are also special nerves which carry sensory stimuli from the internal organs, such as hunger or pain when the source is internal.

In the fishes the brain is largely an enlargement of special sense centers. The anterior end is given over to olfaction, a large part of the mid-

brain to optical activities, and just back of this region is the auditory area. This differentiation is so obvious that these regions are often designated as the "nose-brain," "eye-brain" and the "ear-brain." There is nothing suggestive of the complicated cerebrum of mammals. (Fig. 51.)

The amphibians, of which the frog is a type, begin to show a slight modification in the region of the brain just back of the "nose-brain" but the change is slight. Hardly more can be claimed for the reptiles although the turtle has a conspicuous mass of nerve cells in the floor of the forebrain. (Fig. 52.)

In all of the fishes, amphibians and reptiles the spinal cord is similar and does not exhibit any marked specializations. The brain, however, shows that first one region then another is the supreme and final arbiter, with the control gradually moving toward the anterior end. This important generalization is only evident after one has made a technical study of the fiber tracts within these several parts. The medulla oblongata remains about the same in all. It is a very important region for two reasons: 1. It contains an important relay connection between the spinal cord and brain; 2. From it arise seven of the ten important cranial nerves. All taste and hearing nerves enter the nervous system through the me-

dulla and the control of the muscles of the face, neck, respiration and the heart arise from it. (Fig. 52.)

As soon as one examines the brain of a mammal, dog, sheep, or man, the parts of the brain so evident in the lower vertebrates are nearly all hidden by the cerebrum. Technical studies in the

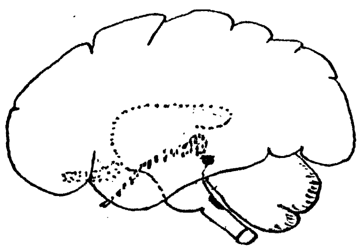


FIGURE 51. Diagram of the human brain showing the same areas as in Figure 50. The "nose brain" area is greatly reduced and drawn out into a minute strand that escaped notice for many years. The "eye" and "ear" areas are proportionately nearly as large. The enormous growth of the cerebral hemisphere overshadows these more primitive structures which continue to be the only avenue over which information of the physical universe reaches this highly specialized region.

phylogeny of the cerebrum trace its origin back into the simple animals such as turtle and frog, but it does not play an important part in their nervous activity. The cerebrum is the highest development that any part of the brain reaches and the climax of its growth is found in man. As soon as the cerebrum became well organized it took over the final control of important bodily re-

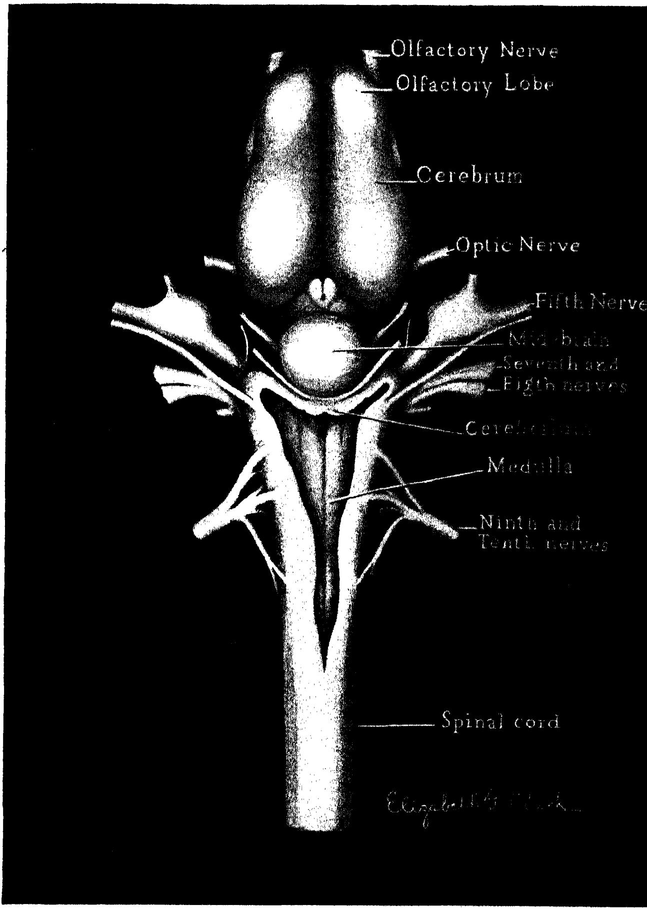


FIGURE 52. The brain and anterior part of the spinal cord of a salamander. The region marked cerebrum is the part that develops into the huge cerebrum of man. Notice that no nerves enter this part of the brain and the same is true for the brain of man. The nerve marked optic nerve enters the midbrain region. Compare the specialization and concentration of nervous tissue in this brain, which is one of the simplest of the vertebrates, with the one shown in Figure 49.

actions, but it has to depend on the other parts of the nervous system for all of its information. It is a mistake to suppose that with the formation of this very large division of the nervous system, new pathways and new relations were established with the sense organs in either the spinal cord or the "old-brain" as the brain of a fish or frog is termed. The same general routes for the fundamental environmental responses persist and can be identified in the brain and spinal cord of man. Several old routes were abandoned when aquatic animals became terrestrial and some new ones occurred from time to time, but the great highways remained.

With the development of the cerebrum a number of new connections were formed and special secondary centers highly modified. Thus there has grown up the modern conception that man is largely dependent on his animal brain for connection with his environment. Such a brief epitome of the phylogenetic history of the central nervous system reveals that man is deeply obligated to his animal ancestry for his nervous system.

The ontogeny of the nervous system has been presented in Chapter V and it is only necessary to refer to the important fact that it is differentiated from the same kind of cells as those which later develop into skin. But before this infolding

takes place, numerous cell divisions occur; and when these are followed backward, one comes to the beginning, a single cell. There is thus an interesting similarity between the simple ameba and the fertilized egg from which grows the mature animal.

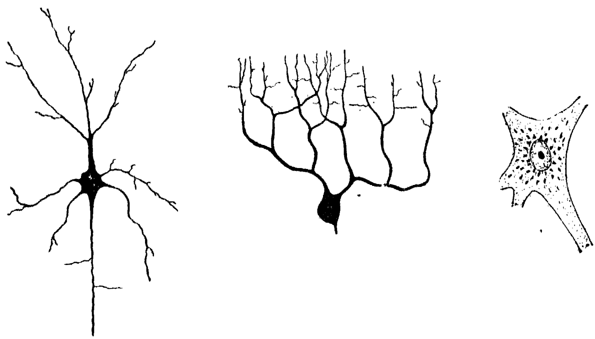


FIGURE 53. Nerve cells in black from the human brain. The one with branches on all surfaces is from the cerebrum while the other is from the cerebellum. The remaining nerve cell shows the cell-body only. There is a prominent nucleus and triangular bodies in the cytoplasm which often undergo change in shape in disease.

There are just two structures which all animals with a differentiated nervous system possess in common: nerve cells and synapses. In the study of all other features of protoplasm, the biological unit, the cell, has been a necessary starting place. What are nerve cells?

This question may seem to be a strange introduction to a discussion of the law of sensation in

animals but nerve cells are the only structures that scientists have ever found which are related to nervous energy. These cells (Fig. 53) are so unlike other cells that an amateur is often perplexed to recognize them. A little study, however, reveals that nearly all nerve cells have one or more special outgrowths or processes, in some instances of enormous length, that serve to connect distant parts of the body with nervous centers. Such cells grow and require nourishment in just the same sense as the muscle cells or skin cells. The technical term, neuron, is given to nerve cells which are to be regarded as existing as morphological units, as being nourished as trophic units and reacting as a chain of physiological units. The outgrowths from the cell body of a neuron are known either as an axon or as dendrites. It is generally agreed by neurologists that a stimulus enters a neuron over a dendrite and leaves over the axon, so that the neuron can be said to have polarity. The diameter of the axon is very minute, but because of its frequent great length the volume of the axon may be 187 times that of the cell body of the neuron. Dendrites are wider, especially close to the cell body, and branch irregularly, while the axon maintains a uniform diameter and branches in a regular manner.

One or two other fundamental facts in regard to nerve cells help us to understand something of

the conditions under which they work. All nerves consist of numerous microscopic threads, each of which is wholly isolated from all others. One has but to think of a telephone cable with several different lines, each of which may be used simultaneously or one or two at a time. There is this fundamental distinction, however, that nerve fibers carry messages only one way. In higher animals every stimulus must enter into connection with the central organ before a reply can be made.

When a message starts out over a given route in a nerve, it does not switch off and continue on any other of the several similar pathways leading to the central nervous organ, because nerve impulses pass across the synapse in one direction only. Thus the expert can designate the several possible pathways over which touch, heat, cold, or pain pass until they reach the brain. This mapping out of the central nervous organ is of great value in detecting the exact location and extent of an injury or disease in the brain.

When the sensory nerve brings its message into the brain, associational nerve cells distribute it to all parts. If a definite response is thus called forth, the motor nerves carry a message to the muscles, which stimulates them to act in a given manner. For some distance sensory nerve fibers and motor fibers may be found in the same nerve bundle of the arm or leg. It is impossible to find more than

three nerves in the whole body of the higher animals that are not mixed, in that they transmit both sensory and motor stimuli. These three are the olfactory, the nerve of smell; the optic, the nerve of sight (even here two kinds exist), and the nerve of hearing. Injury to a nerve in the arm may thus not only destroy all sensation in the hand but also paralyze the muscles of the fingers.

In discussing the subject of reproduction reference was made to the formation of the nervous system from the superficial body cells. (Fig. 26 G-I.) At this state of development, the embryonic nerve cells do not have processes. But before birth or hatching, all of the processes essential to the fundamental vital activities are formed and have taken their place in all parts of the body. The total number of nerve cells found in the nervous system of any given animal, including man, is nearly all grown before birth. The sum of these microscopic units in the cerebrum of man is estimated at the incredible number of 9280 million, all of which were formed before birth. There are many million additional nerve cells in the remainder of the human brain, which also take up their position before birth. This means that the nerve cell machinery for the body of man is ready for use when the child is born.

Man, like all other animals, and in just the same fashion, is surrounded by physical vibrations

which he has defined as light and sound, and by a gaseous medium which gives him what he designates as heat, cold and odors. As already indicated, the central nervous system is entirely encompassed by skin, muscles and bone which prevents these environmental agencies from coming in direct contact with either the brain or spinal cord. But it is self-evident that no animal could adjust itself to its surroundings unless it somehow became aware of such changes. This it does through special cells grouped into special sense organs as the eye or ear or through scattered cells such as those of taste or smell.

In the eye is found a cell that is easily stimulated by light vibrations but does not react to sound vibrations; while in the ear are cells that readily react to sound vibrations but do not appreciate light waves. Any cell that is thus specialized to appreciate changes of a specific kind in its immediate environment is known as a receptor. Such a cell may be located entirely within the body, as in the muscles. Thus there are receptors for light, sound, heat, pain, taste, etc. Some idea of the great difference existing between the several receptors is gained by reviewing the several forms of stimuli that affect them.

Touch and pressure are due to mechanical contact with the number of vibrations varying from one to 1552 per second. There are no organs

in man to respond to the vibrations taking place in the air until they vibrate at least 30 times per second. That vibrations exist in the air below 30 times per second can be proved mechanically although man cannot hear them. The vibrations which are interpreted as sound range from 30 to 30,000 per second and constitute the usual range of the human ear.

The vibrations in the ether are numerous and mostly detected by various mechanical devices. The electric waves range from zero to 30,000 billion vibrations per second; while 3000 billion to 800,000 billion vibrations per second produce radiant heat which is detected by the skin. Light and color are recognized by the eye when the vibrations are from 400,000 billion to 800,000 billion per second. There are no sense organs to recognize the ultra-violet rays which vibrate from 800,000 to 5,100,000 billion times per second; while X-rays are due to ether vibrations ranging between 400,000,000 billion and 6,000,000,000 billion times per second. (Note: These facts on vibration are taken from Herrick's Neurology, page 72.) One wonders what additional information would come to the brain of man if there were sense organs that could respond to these various physical vibrations. The evidence is conclusive that man can be aware of but a small part of the activity in the physical universe, especially

when he relies upon his sense organs alone. This must mean that a limited amount and a selected kind of activity only can normally influence man. The information that comes to him through his senses gives him at best an incomplete and partial story of the events that are constantly going on about him. It is well known that the star-nosed mole has no less than 31,000 special receptors lo-

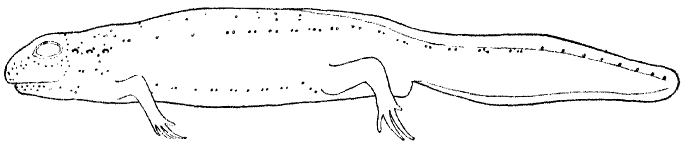


FIGURE 54. A salamander with sense organs distributed along the back, between the legs and especially on the head, that are not found in the higher animals such as snakes, birds and mammals. Each of these sense organs is connected with the brain. Man has no way of learning just what the sensations arising through stimulation of the lateral line organs, as these sense organs are called, mean to a salamander.

cated in the tip of its nose; that many aquatic vertebrates possess numerous special receptors on the head and trunk, and that insects have as many as 2600 receptors on the legs and wings that are believed to be olfactory organs. These three illustrations serve to emphasize the important fact that man is limited in his receptors and that it is probable that many animals are aware of certain forms of environmental changes unappreciated by man because he has no receptors for them. (Fig. 53.)

Thus in these limited relations of the nervous

system to environmental changes barriers of which we are unconscious have been raised. There are entirely different barriers to freedom of action in the hereditary features of the nervous system that direct attention to an entirely different set of limitations. These latter have to do particularly with establishing the routes over which the several classes of stimuli must travel.

The sense organs and nerves just described relate man to his external environment and such grouping of the nervous system leads to the expression so common nowadays, the somatic sensory and motor divisions. But this is to overlook what was for a long time denominated the sympathetic or autonomic part of the nervous system. In this grouping are to be found the nerves that control muscular reactions in the visceral organs and the receptors that carry stimuli from these same organs to the spinal cord and brain. The most recent term for this division is the visceral sensory and motor nerves.

When one attempts to make a clear classification of the stimuli that excite the visceral receptors, one meets with a great dearth of accurate information. It is probable that pressure, chemical changes in the form of hormones, toxicity from the digestive tract and muscular fatigue are among the more important of the visceral sensory stimuli. Just what the stimulus is that excites the

reproductive reactions and upon which the Freudians place so great a stress, we can only conjecture. Until it is more thoroughly analyzed, no fundamental or permanent results will be obtained by this school of psychologists.

It is equally difficult to separate the stimuli associated with the "hunger urge." Muscular contractions in the wall of the stomach seem to be the immediate cause of hunger pangs, but what starts these contractions? Thus far we are studying simply the results and not the causes of such changes. We know equally little about the other "internal urges" which form a prominent part of the modern study of the mind of man. Biology has a long period of technical research ahead of it before such questions can be satisfactorily answered.

There is another common phenomenon of the senses that also awaits further study. This has to do with that strange habit of closing the doors of one sense or another in order not to hear the passing street car or see the trees in the landscape. By diverting the mind, internal, visceral sensations also pass unrecognized. Just what happens awaits discovery in all such instances.

The neuron, which is the basis for all forms of nervous response, cannot act alone. It is important only when in contact with other neurons. While it is thus proper to describe the neuron as a

structural unit, it becomes a functional unit only when united in what is termed the reflex arc. This name was given to the relations between nerve cells before modern neurology had traced out the intricate facts. It was at first thought that the sensory message was reflected over onto the motor nerve cells but it is now known that the process is much more complicated. In all of the higher animals, the possible connections between the incoming sensory stimulus and the associational cells and later with the motor cells are so numerous that one or two pathways must come to dominate, if any response is to eventuate. The term still has some value as a descriptive term, if one is careful not to infer that by using the expression reflex arc, he has really explained what happens.

Before defining the synapse, the second structure which all animals with a nervous system have in common, let us examine some of the implications which the phylogenetic history and the structure of a nerve indicate. It is a strange fact that the most specialized region of the brain must gain its entire information concerning the material universe through the so-called "fish brain" with its three main sets of sense organs which are assisted by the senses of taste and touch. The nerve cells in the cerebrum of man receive their information of the material world and cause the body to react

through routes that have been in existence in the nervous system of vertebrate animals since at least the Devonian Geological epoch, a period of time which must be estimated as not less than several million years. One cannot help wondering what the effect would be if man's cerebrum were in direct connection with his several sense organs and direct instead of second hand information were received by it. In this connection let me quote from one of the foremost neurologists.

"The new brain, with its functions of correlation, is really as old, so far as its beginnings are concerned, as the old brain; but, whereas the latter attains its full development as a reflex and instinctive apparatus in the lower mammals, the former continues to increase in size and importance and it is still increasing in the civilized human races of to-day.

"The kangaroo is one of the lowest types of mammals. A kangaroo with a body weight of 100 pounds has a brain weighing a little less than 2.5 ounces, or a ratio of brain to body weight of 1:711. In the human race this ratio is 1:42. The average brain weight of a European man is about three pounds (1353 grams), the brain being 21 times as heavy as that of the kangaroo of about the same body weight. This increase in the weight of the human brain is almost entirely localized in the association centers of the cerebral cor-

tex and structures immediately dependent upon them, the old brain remaining on practically the same level as in the kangaroo, except for the actual reduction in man of some of the simple sensory apparatus, notably the centers for the sense of smell." (Figs. 50, 51.)

Thus through these ancient routes of travel passes all of man's sensory information. By the right of long usage they have become fixed and are not easily modified. Over these routes we must believe travels all information about food, enemies, dangers, recognition of offspring and similar fundamental and universal stimuli. All of the lower centers in the spinal cord and "old brain" have remained in about the same condition, while a few of the higher, associational, centers in the dorsal portion of the anterior region of the "old brain" have undergone profound changes resulting in what is now termed the "new brain." It seems to the writer that this must mean that the regulation of alimentation, elementary forms of adaptation involving protection and similar reactions are as old as life and that they became fixed in form long before man existed. But man has these common reactions with animals so we must expect that when one of these ancient centers becomes affected that recovery will be of necessity much slower. It is generally conceded that "shell shock" is a form of fear and it is easily conceiv-

able that in the severe cases of shell shock some one of these ancient centers has been affected with the result that recovery must be correspondingly slow. For reason controlled men as they faced undreamed of danger on the fields of Flanders and France, and this aspect of mind in man is largely if not entirely confined to his "new brain." But when these old centers once broke away from the control of the "new brain," they literally assumed an ancient right which only patience and time can restore.

Through this long past history there has been built into the nervous system a definite method of acting. Various attempts have been made to unravel the mystery and these explanations have for a time been accepted. One of the most prominent is the localization hypothesis which happened to hit upon a portion of the correct interpretation. During the evolution of the vertebrate nervous system groups of cells came to act together.

Their purpose at all times was to serve the best interests of the living organism. Modern neurologists have arranged these groupings into four classes. First, the sensations that come to the brain from all of the receptors located on the external surface of the body; secondly, the sensations that come to the brain from the internal receptors

(interoceptors); thirdly, the stimuli that pass from the brain to the voluntary muscles (somatic motor); fourthly, the stimuli that pass to the involuntary muscles (visceral motor). Naturally there are several subdivisions of these, especially the first one, but the more important fact to be kept in mind is that a stimulus must act on some form of receptor, be conducted to the central nervous system and a motor stimulus be sent to certain muscles. This means that a center located in the brain for hearing, seeing, or speaking has reference to but one cluster of cells, associational in character, which belong to the chain of nerve cells necessary for this response. They do not have any significance apart from their relation to the group with which they are accustomed to act. They are simply one of the links in a chain,—a link that happens to be located on the surface of the cerebrum at a given spot.

During the passage of a stimulus along a nerve fiber, energy is required and physical work is done. This is proved by the formation of a definite chemical substance, carbon dioxide, which results from the breaking down of a very small amount of living protoplasm. Such a change is a vital one. This is really one of the great discoveries of the past twenty years in connection with the nervous system as it verifies what has been thought to be

the method accompanying the traveling of a stimulus although no one had proved it. This discovery was made by studying the transmission of a stimulus along the dendritic portion of a sensory nerve. Inasmuch as there does not appear to be anything distinctive about such a stimulus, it is concluded that all stimuli require the same conditions and that carbon dioxide is formed each time a stimulus passes along a nerve fiber. If this conclusion is correct, then one must say that when several nerve reactions are associated as in reflex action that this likewise is a vital process. The carbon dioxide formed in nervous activity is just like the same process in muscles and in so far as exact measurements are at hand, the general metabolism of these highly specialized cells is identical with what takes place in other parts of the body. There is no justification in claiming that special foods are required to make the nervous system go. No new principles have ever been discovered by scientists as they painstakingly applied the recent findings in chemistry to this intricate problem.

It remains to indicate briefly the nature of the synapse deferring some of the implications growing out of the nature of the synapse for the following chapter.

The discussion thus far has omitted all reference to one essential question, i.e., the passing of a

stimulus from one neuron on to the next. There is a clear conviction at present on this question, namely, that each neuron is an independent unit and its connection with other neurons is by contact only. This means that there is a break in the continuity of the nerve pathway. An axon may end through numerous minute terminal branches on a second neuron or in contact with the cell body of such a neuron. The point in a nervous pathway where the stimulus reaches such a structural break,—where it actually passes over into the next neuron is called the synapse. Little is scientifically known about what happens in synapsis. The more synapses in a given route, the longer it takes for a stimulus to reach its destination. The reflex excitability of animals with a synaptic nervous system is greatly increased by strychnin while this drug has no effect on Cœlenterates which do not have the synaptic system. In numerous parts of the spinal cord and brain more than one neuron receives the traveling stimulus. Thus a single sensory stimulus may at a definite place be distributed and redistributed until it reaches the entire nervous system. Just the opposite structural plan also exists by means of which several different stimuli are finally routed into one common center thus bringing about a summation of stimuli. Science is just beginning to realize the nature of

these different connections and it is in this highly, technical field that we may expect future revelations.

All attempts to discover what happens to a stimulus after it enters the brain have thus far been a complete failure. How a heat stimulus can be translated into a specific command to the muscles to contract in a definite manner is unknown. This leaves the relationship of nerve activity to mind, to memory, to instincts and to reflex action yet to be discovered. While the exact connection between a sensory stimulus and a muscular reaction is not fully understood, it is not to be concluded that no progress has been made. There are a host of facts that justify Parker in making the following generalizations: "Not only are our sensations thus activities of the cortical part of the brain, but there is good reason for believing that our whole conscious life is similarly restricted. In the cerebral cortex lies memory with its wealth of stored experiences, in this organ love, hate and fear come into being; here arise the cool deliberations of the man of science, the dreams and aspirations of the poet, the passion of the religious enthusiast, and, when abnormalities intervene, the ravings of the mad man. Contrary to ancient belief, the spleen does not engender temper, nor do the affections flow from

the heart. These and all other like attributes proceed from the brain. And yet the old traditions have so strong a hold upon us that I doubt whether any modern suitor would forward his cause by offering to the lady of his choice the real organ of his affection, his cerebral cortex, rather than his heart."

CHAPTER X

A BIOLOGICAL DISCUSSION OF THE PROBLEM OF LEARNING

How do living things learn? Many would answer this query by simply stating, "They don't" but the steadily accumulating evidence of numerous experiments indicates that the usual mode of action in animals can be modified,—they learn to act differently. This broader use of the word "learning" is being applied to animals as well as man. It is in this sense that we shall try to show that animal experimentation has simplified the problem of learning by discovering some of the factors and limitations under which it seems to take place although the question is far from being solved.

The same methods that have enabled man to master so many of Nature's processes will eventually penetrate the mystery of the working of the mind. The chief difficulty consists in finding suitable methods but with the impetus given to this work by psychologists during the recent war, new devices are rapidly being perfected. So rapid has been the progress in the invention of special

apparatus during the last few years that one is at a loss to know even the meaning and use of the myo-esthesiometer, the dynamometer or the schesi-esthesiometer, each of which is a specially devised apparatus to test muscular sensibility, motor fatigue or static sensations. At the present, much time is being devoted to methods of study and since they are relatively new, they are correspondingly technical. But all of these special devices are used to examine some form of activity that can be tested over and over again.

As indicated in the preceding chapter man has his entire nervous system in common with higher animals and the higher animals have theirs in common with the lower. All of the vertebrates have uniform external receptors (sense organs). similarly placed on the body and responsive to the same form of vibrations and solutions. Each of these receptors is connected by a sensory nerve with either the spinal cord or the "old brain." Through these doors enters all of man's information.

For all of those who wish to approach this problem through biology and the fundamental laws governing the actions of all protoplasm, there are a few generally accepted facts that must be accounted for in any hypothesis. First, when an energy change (vibration) or solution change (chemical change) initiates a stimulus on a nerve

directly or indirectly through a special receptor such as a sound receptor, the changes which occur in the transmitting nerve fiber (axon, dendrite) are the same. The stimulus travels along the fiber accompanied by a series of vital changes resulting in the formation of the waste substance, carbon dioxide. There is no justification for the conclusion that the nerves of sight, hearing or taste are distinct in the way that a stimulus travels over them. The fact that is important is that each one of these sensory nerves is connected with a receptor that is stimulated by one form of energy change, light, sound, etc. If it were possible to stimulate the receptor cells in the eye by sound vibrations, the resulting stimulus in passing over the nerve fibers of the optic nerve would cause just the same changes in this nerve that the regular light stimulus produces.

This is really one of the very important conclusions which biology contributes to our problem. It is made more emphatic as one tries to recall his own attempts to understand how the inverted image due to the shape of the lens in the eye travels along the optic nerve. The explanation which science offers is that, so far as the stimulus is concerned, the inverted image is just like any other sensory stimulus passing along a nerve fiber.

Each type of receptor and the nerve connected with it work together as a unit. This relation is

similar to the following: If one takes a brass rod and strikes it, sound waves travel along the length of the rod; or if one were to apply heat to one end of this same rod, in a short time the heat would be carried along the whole length; or, this same brass rod may be attached to an electric current and the current will flow through it. The kind of energy change will depend upon the will of the experimenter but the brass rod does not change during the passage of the sound wave, heat wave, or electric current. If one wished to carry on all three of these experiments at once, and leave the results distinct, he would need three brass rods. This is what Nature requires in animals and man, —a separate nerve for each receptor. While these several nerves have each an independent history, their present service seems to be identical, i.e., to carry stimuli from sense organs on the surface of the body to the spinal cord and brain.

Secondly, the main business of a receptor is to be sensitive to specific energy changes in the environment and the sole work of the nerves immediately associated with these receptors is to transmit the respective stimuli received from each receptor. Thus far the analysis is clear and the evidence conclusive. But how does the stimulus pass from a receptor to a nerve fiber; from one nerve fiber to another; and finally from a nerve fiber to a muscle or gland.

There is no question of fact about whether stimuli actually do pass from one structure to another, the question is how do they pass. Until more is known, science can only describe as clearly as possible the relations existing between such structures. These fall into three classes: (a) In a general way one may say that most receptors are relatively simple cells that have minute dendritic branches in contact with them. The best technique has failed to reveal a continuous structural union between such cells and the nerve fibers that enclose them. They are in contact only. No one has explained how a sound stimulus is able to pass from the sound receptor on to the dendrites of the auditory nerve. (b) A similar difficulty is met after the stimulus has begun to travel toward the brain, after it has been passed by the receptor on to the dendrite and in all of those cases where dendritic branches act as receptors a similar condition exists. There are no single neurones that extend from a receptor to the cerebrum. The message has to be carried forward by a second neuron, a third, a fourth, etc. Each of these successive neurones is merely in contact, the end branches of one touching the receiving branches of the neuron next in the route. There are numerous breaks in the conducting fiber tracts from skin to brain that are easily recognized by the student of structural neurology. (c) In all cases of

movement a stimulus must reach the cells in certain muscles. Here scientists have looked in vain for some intimate union between the peculiar terminal branches (end-plate) of a motor axon and the muscle cell. They are in contact only.

Because of these three structural arrangements in the nervous system, one may say that there are three types of synapses. First, the type that exists between such a receptor as sound and the dendritic branches of the auditory nerve; secondly, the relations that exist between the terminal branches of one nerve fiber and the receiving branches of a second; thirdly, the conditions that obtain between a motor end-plate and a muscle cell. There are several modifications which result in stimuli being distributed over several routes or just the opposite, when different stimuli are concentrated to one point.

Somewhere between the receptor and the muscle, the stimulus is modified because when light or sound waves are sent directly over a motor nerve, these waves do not cause coördinated movement as they do when they enter through receptors for light and sound. Most students of this problem are convinced that important changes are introduced in synapsis because of the evidence already cited in connection with the movement of a stimulus along a nerve and the general biological evidence that the main function of the cell body

has to do with the utilization of energy in order to keep the nerve cells going. Somewhere there must be a portion of a neuron devoted to metabolism and as a nucleus is always necessary for these complicated energy changes, scientists have held steadily to the view that the cell body of the neuron is mainly concerned with nutritive reactions. This leaves the synapse as the essentially new relation introduced between these biological units, the neurons. Critical experiments demonstrate that the synapse is more easily fatigued than any other part of the neuron and also that it is more susceptible to drugs and poisons.

These structures and relations are all that one can find in the nervous system. They are arranged with infinite complexity and grouped into numerous minute and large pathways. Each of the two functional sensory systems in the nervous system, the somatic sensory and visceral sensory, occupy specific places in the cord and brain and deliver the benefits of their information over to either the somatic motor or visceral motor as the need of the organism requires. This usually results in some form of movement in the body.

Movement seems to be a strange device to rely upon for all of our information about the mental life of animals yet there is nothing else in the final analysis. Man speaks, writes, runs, waves

his arms,—all of which are movements to which we have agreed to attach a certain meaning. There is some difficulty in always understanding our human definitions but this is a minor difficulty in comparison with the study of animals where all of our conclusions must be drawn from a study of their movements to which we and not they give a meaning.

When we find that animals move toward a given substance as bees do toward cane sugar, and are indifferent to saccharine, we conclude that bees like cane sugar. In the experiments which are to follow illustrating the study of learning in animals, note that movement is the key used in unlocking this problem.

In times past much was written about the part played by reflex action as an elementary form of nervous activity and many animals were studied in the expectation of finding that somewhere the relations were so simple that the physiological aspects of reflex action could be analyzed. Parker's numerous studies on the elementary nervous system of animals throw no new light on the real character of a reflex act. As soon as such simple animals as earthworms are studied the nervous mechanism is found to be far too complex to permit of simple reflexes between a receptor and effector such as Parker describes in the Cœlenterate Metridium. Between these two structures, receptor

and effector in the worm occur several kinds of nerve cells limited entirely to the ganglia which receive stimuli indirectly and indirectly pass on stimuli to the muscles. No one understands what takes place in these associational nerve cells as they are termed; so that the actual mechanism of reflex action is not understood. It really explains nothing to say that it is a reflex act. The nervous reactions which man is not aware of while they are taking place are for convenience of description termed reflex but we do not know that they are in any way different from those reactions of which he is conscious. Hence it does not seem that much is to be gained by an elaborate presentation of reflex action as it is related to learning.

In 1912 Yerkes gave an account of his experiments in trying to modify the behavior of earthworms. He devised a simple apparatus (Fig. 55), by means of which he was able to test the ability of earthworms to "learn" to follow a simple path and to avoid an injurious chemical (or electrical) stimulus by reacting negatively to a peculiar tactual stimulus which regularly preceded the chemical stimulus. He had in mind two questions: (1) Can the worm profit by experience: and (2) can it "associate" the tactual stimulus with the chemical and acquire the habit of regularly responding to the sandpaper as though it anticipated the unpleasant stimulus from which it always did move

away. The animal was usually given five trials on a single day. From October 12, 1911, to

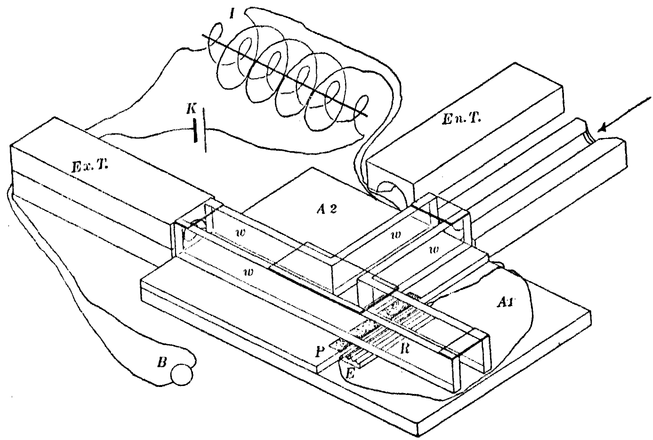


FIGURE 55. Perspective of T apparatus for study of habit formation in the earthworm; A1, plate-glass base for parts of apparatus; A2, layers of white blotting paper covering approximately two-thirds of A1; w, w, w, w, plate-glass walls of T-shaped passage-way; En. T., wooden entrance tube, lined with moistened blotting paper, from which worm enters passage-way, as indicated by arrow (the cover of the tube is shown removed; Ex. T., wooden exit tube in position for reception of worm as it emerges from open arm of glass T (in this case, the cover is in position); P, strip of sandpaper resting on A2 and extending across passage-way; E, pieces of copper wire serving as electrodes, insulated and kept at fixed distances from one another by the corrugations of the strip of rubber, R; I, inductorium, wires from the secondary coil of which terminate in the electrodes at E; K, key in primary circuit of inductorium; B, dry cell. From Yerkes, Intelligence of Earthworms, Jour. Animal Behavior, vol. 2, p. 332, 1912.

April 30, 1912, a single worm was given 850 lessons (trials) in passing through the labyrinth. In the latter part of the experiments, the worm

was seldom directly stimulated and usually took the right turn with a fair degree of accuracy.

In view of the positiveness of these results, he next tried an unusual experiment, i.e., he cut off that part of the body containing the "brain." These worms are able to regenerate such lost parts and the idea was to determine whether the previously acquired habits were located in the brain or generally distributed in the nervous system. Forty hours after the operation, the lessons were begun again. "The worm moved forward, more slowly and continuously than before the operation, into the middle of the stem. Having reached the common wall of the arms it turned to the left and five times pushed forward to the sandpaper, each time withdrawing upon contact. As it searched with the cut end for a way of escape, the 'tail,' became active and moved about as if 'feeling' for a path. Shortly a turn toward the right was made and, with repeated attempts to crawl up the glass wall, the worm approached the exit tube. The instant the 'head' end came in contact with the moist lining of the tube the worm pushed forward as in 'recognition' of the retreat.

"The correct performance of a thoroughly ingrained habitual act of the kind studied in this investigation is not dependent upon the 'brain' (portions of the nervous system carried by the five anterior segments), since the worm reacts ap-

propriately within a few hours after its removal. As the brain regenerates, the worm exhibits increased initiative, its behavior becomes less automatic, more variable. Two months after the removal of the 'brain,' during the last four weeks of which period no training was given, the habits had completely disappeared. Systematic training of two weeks resulted in the partial reacquisition of the original direction habit. The various facts recorded in this investigation indicate that the removal and the regeneration of the first five segments resulted in the development of a worm strikingly different in behavior from the original worm." *

Before indicating the significance of this method of training, we must examine the methods employed in one of the lower vertebrates, the common frogs † and the racoon, one of the mammals.

Frogs are like toads in their method of capturing food. The tongue covered with a sticky mucous is quickly thrown out striking the passing insect which is captured just as a fly is caught when it alights on fly-paper. Schaffer constructed a cage with natural conditions such as water, stones, moss, etc., closely imitating the environment of the animals to be experimented on. The common

* Yerkes: The Intelligence of Earthworms, Jour. Animal Behavior, 1912, No. 5, Vol. II.

† Schaffer: Habit Formation in Frogs, Journal Animal Rehavior, 1911, Vol. I.

wood frog, technically named, Rana sylvatica, was selected for his experiments. He writes: "July 29, I placed 30 of the hairy caterpillars in the cage. Rana sylvatica attempted to eat a caterpillar seven different times within an hour but rejected it each time. Following these trials no other caterpillars were visibly reacted to. By attempting to eat a caterpillar and then rejecting it is meant this: The frog shot out the tongue in the normal manner, bringing the caterpillar back to the mouth, then extruding the tongue slowly, slightly wriggling it. In most cases this muscular wriggling freed the caterpillar from the tongue; if it did not, the withdrawal of the tongue into the mouth scraped off the caterpillar in nearly every case. On August 9, 12:30, the caterpillar was placed in the cage again; Rana sylvatica reacted first by making two short hops to orient so as to look directly at the caterpillar. (The caterpillar was about 5 cm. in front of the frog.) The head of the frog was then slowly lowered and brought forward toward the caterpillar, but I could not see that the tongue was shot out, although I watched especially to see if this would happen. In a second or two the head was lurched forward a little more and then the tongue was very slowly extended, barely touching the caterpillar. The tongue was now withdrawn and then suddenly extruded, with what appeared as a very slight attempt to shake

the caterpillar off. The caterpillar elicited no further response during the next forty-five minutes. For four days the frogs were scantily fed and then a caterpillar was put in the cage. Rana sylvatica took no notice of it." This frog had formed the habit of avoiding hairy caterpillars in seven trials, but when the green frog is given lessons in escaping from a single labyrinth, about one hundred were necessary before the right route was regularly taken.

Cole made his observations on racoons. The animals were rewarded with food on the successful working out of their lesson. He began with simple tasks and increased the details until all of the animals succeeded in learning to work seven fastenings: namely, two buttons, two bolts, lifted by a pull on each of two loops hung in different parts of a large box, one thumb latch, one bolt raised by the animals, mounting a platform and a horizontal hook placed at the left side of the door. In boxes of two to seven fastenings there is almost no tendency to follow a routine order in undoing them.

As a result of numerous trials extending over several months, it was concluded in part that the long practiced motor associations show a good degree of permanence, others are very transient. The racoon presents two types of learning and two types of forgetting.

Cole also made tests with colors and sound. One table will adequately illustrate the method. High tone was used as a signal for food and low tone a signal for no-food.

Number of trials	right	wrong
High-tone, a signal for food.		
1- 50	37	13
51-100	44	6
101-130	27	3
Low-tone, signal for no-food.		
1- 50	34	16
51-100	38	12
101-150	48	2
151-200	50	0

Several volumes might be devoted to a detailed description of similar experiments. The principle is the same whether the animal is unicellular or multicellular; whether it possesses an organized nervous system, one that is diffused or none at all. In all instances the sole criterion upon which it is judged is the way the animals move.

Each of the animals cited above had acquired certain habits that were modified by the experiment or entirely new ones were learned. The earthworm is a nocturnal animal that retires under a stone or into its burrow during the day-time.

All that was necessary usually was to remove the wooden cover from the entrance tube (Fig. 55), and the worm would begin to crawl forward. As it entered the exit tube, it found relief from the annoying stimulus of the bright light.

Suspended hairy caterpillars swinging just in front of the nose of a hungry frog furnished a tempting satisfaction to the hunger urge. But the hairs evidently irritated the tongue and the reactions to this stimulus after a few trials made the frog prefer going hungry to trying to eat the hairy caterpillars. The earthworm was punished by exposing its body to a bright light and the frog was punished by tempting it to eat something that would at least be unpleasant if not actually painful.

The hungry racoons were allowed a drink of milk or a reward of sugar for successfully executing their "lesson." After they had eaten, their time in performing an experiment was slower "due to approaching satiety" writes Cole. When the animals were too hungry, they were so eager to secure food that it invariably prolonged the time of escape from the experiment box. The racoons were rewarded by food for their success.

How natural it all sounds to read "There appear to be 'good' and 'bad' days for the earthworm. When it does what the teacher (experimenter) wishes, the worm has a good day, when

he does not then it is a bad day. The problem of teaching the racoon was easily compared to this same problem in man because the racoon has but 'two types of learning and two types of forgetting.' "

The earthworm and frog were stimulated through their receptors for light principally while the racoon was allowed to satisfy its hunger and thus was stimulated indirectly through its interoreceptors. In each of these striking examples of learning, the receptors were employed as the initial avenue of approach. Some natural stimulus was selected and one to which the animal would naturally respond. From the discussion in the earlier part of this chapter, it is clear that when such a stimulus started over an appropriate sense organ that its main routes in the nervous system and final destination were pre-determined. This would be true whether the animal was being experimented on by Nature or by Man.

On the other hand, there is another factor to be reckoned with, for it is very much doubted if a single sensory impulse can alone produce a reaction. The keenest thinkers recognize that elementary reflexes are impossible in any of the higher animals because normal responses in them are dependent upon sensory impulses from various sources. There is what is termed a summing

up of sensory impulses within the central nervous system. Such an inter-acting relationship brings every reflex act as well as instincts, habits and learning under a general law, known as the integrative action of the nervous system. For the reaction of an animal is not the result of a single sensory impulse but an association of impulses of varying degrees of intensity. While the earthworm was stimulated by direct sunlight, there was also the absence of stimuli from its natural burrow in the earth and the substitution of stimuli from moist filter paper. All of Yerkes' "lessons" with the earthworm were given under but partially normal conditions.

It is important to keep in mind the significance of the functional divisions of the nervous system which clearly proves that there are no breaks in the entire circuit from receptor to effector. This is especially evident in all vertebrates which places a different interpretation on circumscribed areas in the cerebrum than customarily given. The so-called speech or hearing center is simply one of the relay centers in the route that happens to lie on the surface of the brain,—a group of nerve cells readily accessible for experimental treatment. They are neither isolated nor necessarily terminal but connected by nerve tracts with other centers

just as specific in their relations as these are in theirs. (Fig. 56.)

All of the elementary reactions of vertebrates are carried on by fishes, frogs or snakes although

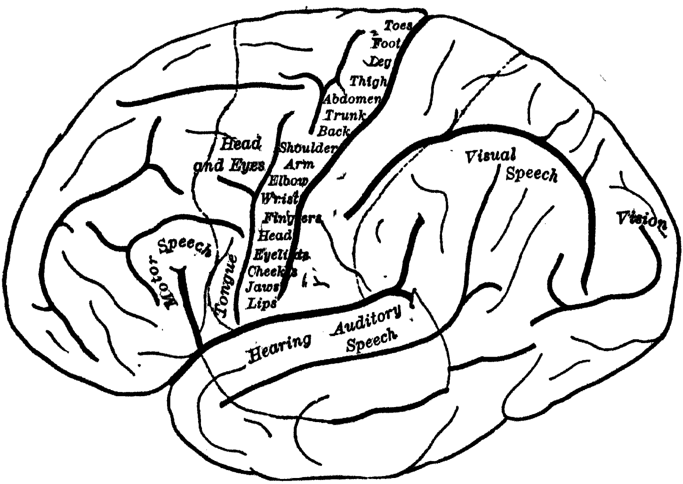


FIGURE 56. Outline of the cerebral hemisphere from the side showing some of the areas where certain mental activities occur on the surface. This is usually spoken of as localization. It really means that the nervous pathway or tracts over which certain activities, such as those which control the muscles of foot or jaws or visual speech, have some of the nerve cells located on the surface of the brain at the place indicated. An electrical stimulus can be applied to these cells and a definite response secured. From Starr's Nervous and Mental Diseases.

none of them possesses that portion of the brain known as cerebrum or "new brain." If it can be said that such animals acquire habits and learn, then it is evident that the cerebrum is not neces-

sary in such reactions. In each of these different groups, first one region of the "old brain," then another comes to dominate and regulate the activities of the animal. The cerebellum performs this rôle in certain fishes, while the mid-brain is in control in frogs. It is only among the higher animals and man that the great regulating center for all of the higher mental processes is located in the cerebrum. The halves of the cerebrum are connected by a prominent bridge (corpus callosum) that brings all of the regions in this complex organ into intimate connection. In eminent men so far studied this bridge is much thicker than in the brains of savages or ignorant workmen, clearly indicating that such an extensive association between the parts of the "new brain" is significant.

The learning experiments in animals through the use of common stimuli aimed to have each of the animals exhibit a specific series of reactions. It was hoped to establish new habits which would be retained and in each case the experimenter was successful. When one tries now to formulate an hypothesis of just how this was done, he enters a field of intense controversy.

Nature has always been a stern teacher for the animals that have even survived. Habits and instincts have become deeply ingrained into their very being. Those with a complex brain and a

wider range of choice exhibit more variety in their mental reactions. But all are similar in that they have repeatedly gone through one set of reactions which proved to be helpful to them. Those reactions that were not useful were not repeated and so did not become fixed nor perfected. Nature rewarded the animal that made one set of responses and punished this same animal when it made another. Darwin termed this method the Struggle for Existence. By this method animals learned or acquired definite mental habits and instincts.

It seems safe to assume that trial and error played a large part in fixing these habits before they became perfect responses. Such a series of reactions would follow from the variety of stimuli that would impinge on the experimenting organism. Gradually one set of sensory impulses would dominate in the several possible reflexes thus resulting in a specific reaction. Such a reaction, even the very simplest, would have associated with it numerous other incomplete reactions that would contribute to its modification,—all of which would be integrated into one.

There is no experimental evidence that reactions become established except through long usage which means that they were repeated many times. It is conceivable that such repetitions gradually influenced successive synapses with each

one making its own contribution to the moving impulses until it finally became a motor message. If such is the history through which habits and instincts have passed, then we have a foundation upon which modifications of habits can be constructed.

It required numerous trials to teach the earthworm the difference between success and error. The same combination of reactions had to be done over and over. When the earthworm grew a new brain, this in turn had to be trained. When one contrasts the structural possibilities of such a simple animal as the earthworm with the higher vertebrates, there is an almost endless multiplication of associational routes over which sensory impulses and the attendant reflexes may pass. In the highest group of all the vertebrates, the mammals, there is in addition to the regular brain the so-called "new brain" which receives impulses from all over the body. This is the first time in the history of animals that one single region becomes the regulating center for all activities. From it impulses travel which influence every structure in the body. Here are made possible associations which are not found elsewhere in the nervous system. In order that it should come to have such a dominating influence, the powers that it possesses must have come from other parts of the brain. Some of the activities that were once

regulated by the "old brain" are now controlled by the cerebrum. In this shifting of responsibility there have been developed more possibilities of choice when a reaction is needed in this "new brain" than in any other part of the nervous system. The habits and instincts of such animals are easily modified in comparison with all other animals. The racoon was able to learn a complicated lesson in a few trials.

However, nothing new is introduced as to method and no new kind of reflex action nor new type of nerve impulse is evident in any of the reactions that are regulated by the "new brain." There is not found any new type of synapsis nor is there any structural evidence that habits or learning alter one or more of the synapses in the route over which they travel. We must formulate our procedure with the same tools that nature has dealt with in teaching animals since they first began reacting to differential stimuli.

All of a child's information, then, enters through his receptor. These will vary with his heredity as will all other parts of his body and in no other way. There is a given range of vision, audition, sense of taste or smell. His place in this range, poor, medium, good, is fixed before birth. Through his inheritance is thus fixed the limitations under which his receptors will respond. The

deaf cannot be made to hear nor the near sighted given normal eyes.

Because of man's biological origin and relation to the fundamental laws of protoplasm, he is governed by the same laws as are all other animals. No new methods of procedure that are essentially fundamental have ever been discovered for man. We must postulate for him, then, the same methods of learning that Nature has always used with animals. New devices will be employed from time to time and the elimination of material that was once held to be important will be made but in the training of the mind in all of its early stages, there will be the simple reward and punishment suggestion during which time definite synapses are becoming accustomed to a given reaction. These once established, the training of a new set can be begun. Thoroughness takes on a new meaning according to this hypothesis. It grows out of the biological necessity of training synapses to respond similarly each time and no one can predict in advance how many times the process must be gone through with a given individual nor how adjustable and flexible an individual will become until training has been applied.

The old adage that we are creatures of habit comes thus to have a significant meaning in this

light. For before a habit is fixed, the group of reactions which result in a specific response have to be repeated many times. A habit is made up of many reflex actions in which one combination finally dominates over all of the other possible reactions. In this as in the simple nervous process, it is the training of the synapses that must take place. The formation of habits is well illustrated in the method employed in the training of animals where an almost endless series of repetitions is used in fixing the habit. Habits of cleanliness are instilled into a child only by constantly requiring that he wash his hands before coming to the table to eat and there does not appear to be anything distinctively different between the methods of teaching the child or the animal.

It is a fact that all are agreed upon, that the distinctive aspects of mind which Parker summarizes at the close of the last chapter, are only found in man who possesses the largest cerebrum of any animal. The inference that somehow in this structure there are resident the qualities that make these characteristics of the mind possible cannot be escaped because of the discoveries of the last few years in regard to the persistence of the "old brain" with but slight changes from the fishes on to man.

The technical discoveries of science are clearly

revealing that we shall be able to understand how many of the obscure mental processes occur. Looking at the whole problem from the scientific standpoint one is forced to express the wish that there be less generalization and more study of facts. We seem to be living in an age when facts are not especially wanted. They interfere with our generalizations. Real progress cannot ignore them.

CHAPTER XI

BIOLOGY AND PROGRESS

"MANY discoveries are reserved for the ages still to be, when our memory shall have perished. The world is a poor affair if it does not contain matter for investigation for the whole world in every age. . . . Nature does not reveal all her secrets at once. . . . Of one of them this age will catch a glimpse, of another the age that will come after."*

Whatever may become of the philosophical idea of progress in the future, at present it holds a place in our affections second only to religion as we proudly assemble our discoveries and indicate their profitableness to man.

It was a long time before science became organized into a body of knowledge that was of service to mankind. One of the main difficulties that beset the early workers was the lack of a distinctive system or method of making investigations and indicating their significance. As men gradually freed themselves from the dogmas of their times and gave to their observations a genetic relationship, a method of work was formulated that was destined to have profound influence upon all realms of knowledge.

*Seneca, Natural Questions, book VII, p. 31.

This way of working and thinking has come to be known as the Scientific Method. It has been adopted by departments of learning other than the sciences until we have well-known books on the scientific method in philosophy, religion and education. If we are to designate the relation of biology to progress, we must state in outline the plan of the scientific method.

The scientific method can be traced back into the misty past where some unknown men made accurate observations on the heavenly bodies. The reason that their conclusions have stood the test of time is due to the fact that they employed a method which was in reality the modern cause and effect process. Hipparchus as early as 160 B. C. made his deduction after a study of the causes associated with the revolution of many of the heavenly bodies. After him a period of 300 years elapsed before this method was again successfully employed and the conclusions of Ptolemy, 140 A. D., still constitute an important part of the fundamental knowledge of our oldest science, Astronomy.

In chemistry this idea grew out of the experimental work of the alchemists as they attempted to transmute the metals but it was not until many years after their futile efforts that Lavoisier in about 1870 established certain fundamental relationships in chemical reactions and chemistry

began to be an exact science. He was the first to show that a chemical equation was really an algebraic equation also and when three factors were given, the missing one could be computed. This implied definite causal relations and from this time on to the present, the scientific method has superseded all others.

Biology began to feel the influence of the relationship idea much earlier than chemistry. Several workers had been trying to show that animals and plants could be arranged into groups before Linnaeus in 1758 devised a scheme of classification based on relationships that has been retained until the present. Numerous workers on embryology laid special emphasis on the long series of changes between the ovum and the chick before the time of Darwin. Here one finds the names of such famous men as Harvey, Malphighi, Wolf and Von Baer. But it was finally reserved for Darwin to apply the method of cause and effect in such a manner as to revolutionize the manner of thinking not only of biologists but of those in other realms of knowledge as well. Let him tell how he did it. "By collecting all facts which bore in any way on the variation of animals and plants under domestication and nature, some light might perhaps be thrown on the whole subject. My first note-book was opened in July, 1837. I worked on true Baconian principles, and, without

any theory, collected facts on a wholesale scale, more especially with respect to domesticated production, by printed inquiries, by conversation with skillful breeders and gardeners, by extensive reading. When I see the list of books of all kinds which I read and abstracted, including whole series of Journals and Transactions, I am surprised at my own industry. I soon perceived that selection was the keynote of man's success in making useful races of animals and plants. But how selection could be applied to organisms living in a state of nature remained for some time a mystery."

If we separate the scientific method into its parts, a clearer notion of how it operates and how we may operate it, is obtained. These parts are cause, effect, classification.

1. The scientific method implies that the happenings of to-day are the outgrowth and continuation of some previous happenings which it is customary to speak of as causes. A metaphysical first cause has no place in the scientific method simply because it is something that is unknown. When a happening is repeatedly found to be associated with an equally constant result, it is spoken of as the cause of the result. In the refinements of analysis it is proper to ask why it is a cause, whether it is the only cause, or what causes are associated in producing a given result.

2. When a given fact is observed to be a cause

then the one or more happenings which it initiates are designated as effects. There is thus a definite relationship between cause and effect which constitutes the essence of the scientific method. It implies that the results cannot take place without a given cause. When this is applied to our everyday knowledge, one says that the leaves appear in their season and that a maple leaf does not grow on an elm tree. Fruit time and harvest are preceded by an orderly series of events, each linked to each as in a chain. This principle is not limited to organic life. The passing street car, the torrential brook in spring time freshets or the destructive tornado are to be understood only after a close study of certain particular causes. To express the same idea in a different way, one may say that every happening, every material thing in the universe of to-day has had a continuous history. The happenings of today become the history of to-morrow and it is necessary to know the history of yesterday, if one would understand the happenings of to-day. The scientific method implies that all observations shall be made in such a way that they can be repeated, controlled and verified by subsequent observers. The word "controlled" has a technical meaning referring especially to verified, repeated experiments.

3. Simply to trace the relationship between

cause and effect is to leave incomplete the scientific method. The final and significant step in the process is to organize into broad generalizations the conclusions which the detailed observations have supplied.

Each new fact placed in its proper relation to a larger grouping of facts enables us by so much to anticipate nature, in short, sets us free and gives new meaning to the saying "The truth shall make you free." So far as the existence of the accumulated facts and generalizations of science are concerned, they have existed as long as man has lived and many of them much longer. But they were unknown to early man and, so far as he could take advantage of them, non-existent. In the same way they are non-existent for many persons even in this age because they have no actual knowledge of them. The more man comes to understand the relationships existing between antecedent happenings and consequent results, the greater is his progress and the more economy he can introduce into his thinking.

We may regard the scientific method as furnishing the rules governing man's attempt to acquire knowledge of Nature and supplying the facts which every one is required to consider who offers a philosophic explanation of life.

Liebig wrote in his old age "The majority of our controversies arise from the fact that we are

too much in the habit of attributing to one cause, that which is produced by several." This important generalization needs to be emphasized in our time when hasty conclusions are being spread abroad as a "cure all" for the conditions of this age.

Man has come to have almost complete control of the inorganic universe through the application of the scientific method. The great generalizations of science are established and he now turns his attention to their application. In all of the manifold applications which are being made, man is able actually to create very little because the vaster portion of Nature was already in existence before man appeared. As he rushes hither and yon every now and then he discovers that the only sudden thing in Nature is a catastrophe which is always destructive, and he is driven to stop and ponder over his inability to produce sudden changes. After a time he may come to realize that his difficulty is that he has not recognized the limitations of his own body and the laws that govern it as well as the laws that regulate the non-living world. Herein lies the reason for the discussion that follows, namely, the limitations which Nature has placed and their relation to progress.

Has structural evolution come to an end? Yes, it ended when *homo sapiens* became distinct from

the palæontologically extinct races of men. With the advent of modern man, there was organized an animal with relatively simple digestive organs, teeth and limbs but with a more highly specialized brain than any other living thing, and it is to this latter organ that man owes his superiority. The body of man has not undergone any marked change as far back as records are available nor should we expect his body to change much in the future. It is more likely to deteriorate than to advance because of his recent habits of living in comfort and ease. The draft revealed an amazing amount of physical unfitness in our youths that furnishes a striking example of the changes that are taking place in man in this age.

Early in the history of man's life on the earth, he became isolated into tribes which gradually emerged into distinct races. But with modern methods of communication, racial barriers are breaking down and the distinctiveness of racial type is slowly emerging into a type common to all races. With all of these changes, however, the result is clearly a man and there is nothing to indicate that he will become anything else. Thus when *homo sapiens* became distinct, definite limits were established and beyond these he has never gone.

One usually thinks of man as free to do what he will, go where he wishes and live as he chooses

but in all of his freedom, he is minutely regulated by chemical messengers. These chemical messengers are the products of several different glands in his body which have been doing their important work in ages past although discovered but yesterday. They are found in a group of glands which discharge their secretions directly into the blood. In all cases this secretion has a specific effect on some other organ or physiological process. So important are the products of these glands that most of us are familiar with their names. They are the thyroid, thymus, suprarenal, pituitary body and pineal; the latter two are a part of the brain. In addition to these glands, there are special clusters of cells that add their secretion to those already in the blood and are found in the pancreas, ovary, testis, the wall of the digestive canal and in other parts of the body as well.

Each of these secretions whether from a gland or cluster of cells is distinctive in its reactions. The lack of the thymus product is associated with retarded physical and mental growth in children. Often this difficulty can be overcome by administering the extract of thymus or thyroid from an animal and the stunted human being begins to develop into a normal child. Truly, a marvelous discovery! The most of us can feel grateful that our thymus and thyroid glands were properly

active and that each sent out its chemical messenger to speed on our normal development. On the other hand, excessive activity of some of these glands may cause serious results. The overactivity of the pituitary body stimulates the body to excessive growth and so we have an explanation of gigantism in man. It is a pathological product. Similarly lack of secretion in the pituitary body results in obesity which is also a pathological state.

The little thought that is given to the sex glands usually centers around their production of eggs and sperms which is but one aspect of their regular activity for we now know that the cells which do not grow into sex products, produce secretions that pass into the blood and have an important influence in shaping those general characters which are distinctively male or female such as the quality of the voice and the combination of qualities which go to constitute a womanly woman and a manly man. Experiments on rats, for example, in which the ovaries were removed and testes grafted into the body of the spaded female, resulted in causing the female rat to take on male qualities. When this experiment was reversed, a similar change was produced in the male. Thus indicating the very evident part which chemical messengers as these secretions are termed play in modifying the body.

The much heralded attempts to produce the "eternal fountain of youth" for man by grafting some interstitial cells from the testis of a young man into the body of an old man, have met with failure as they must because it is an attempt to make a small part of the entire living machine come under the control of a minute fresh stimulus. The body of man has never been regulated exclusively by any one internal secretion. There are many of them, each doing its specific work,—all regulating the normal changes in his body. Some have their greatest importance in early youth, others during adolescence, and still others every time we eat. Man is abnormal when these secretions do not act in their season, for some accelerate, others retard until a delicate balance is struck which we have come to define as the normal for man. It is thus folly to expect that the body will respond to secretions taken out of their relation to all other conditions or that some one will dominate over all others. What all such studies really reveal that is important is the marvelous restrictions and limitations under which man lives. In whatever attitude of mind one approaches this general theme, it throws a new light on the wonderful organization of a living human being. As soon as he departs from the delicate balance that Nature has developed in him, he departs in some concrete particular phase from

the average man. There is nothing in all of this delicate balancing that man has created nor that he can set aside. He is held fast not only by the restrictions of the broad fundamental laws of all life but also by these chemical messengers. His progress has to conform or take place under these conditions.

Every ambitious person desires to be efficient in the particular tasks undertaken. He is conscious of some bodily conditions that hinder him at times such as a severe cold or a headache from indigestion. These he easily learns to control. But there are other fundamental conditions that are not as easily understood and which he can but partly regulate. These are those variable bodily conditions associated with the changes that occur every twenty-four hours. When does the body seem most vigorous? When is vitality the lowest in each daily cycle?

The second question can be answered by any experienced nurse or physician for the majority of people die near three o'clock in the morning and this is the period when most care has to be taken in severe cases of illness as death is more likely unless the body is helped over this natural period of depression.

Beginning with this period of low vital state, there is a gradual rise in vigor until one comes to his maximum and then a slow decline sets in. I

know of no facts which establish the time when the peak of vigor is reached in the daily rhythm nor how long it remains at this level. There is certainly a large range of variation in this physiological trait. It is apparent that one can keep the fact in mind and slowly train the body so as to take advantage of this characteristic. There are times when a big task seems impossible, which in the morning resolves itself as easily as sugar-snow melts before the spring sun. The whole quality of ability that one is thus able to utilize is at its best.

The limitations of the daily rhythm and the significance of chemical messengers are presented because of their intimate and continuous regulatory influence. They are but examples of several similar conditions that operate continuously in shaping man's responses. It is an easy task now to summarize the relations of Biology to progress because we recognize the direction in which they lie.

By progress we mean the increase in the scope of our actual knowledge of the laws of life, particularly as they apply to man. For his activities are inseparably dependent on that fundamental organization which he has in common with the animals and which is the central theme of this book. However man must do more than merely

comprehend these relations,—he must apply them in his daily round of activities.

As already indicated, there is a clear conviction on the part of scientists that man's body will not undergo any marked progressive changes in the future. For some reason not yet perceived man's body has shown but a limited range of variation when compared with the flexibility of such a family of fish as the Salmonidae, where one finds white-fish, frost-fish, trout, charrs and salmon representing several distinct species; but in the Hominidae, the human family, there is but one species. The varieties of man are all fertile *inter se* which is one of the criteria of species. We know nearly all that we shall ever know about the physical range of variation in man. To be sure refinements of our knowledge will be added for many years but these additions will not reveal how man can be permanently modified. Thus we do not look for progress to indicate how a structurally changing human body can be brought about. Man must get along with the kind of body that he has always had.

As long as man exists, some method must be employed to keep his body going for his many physiological processes all utilize energy; and the changing of potential into kinetic energy is a basal relation solved long ago. Man will become more

skilful in satisfying this need but not in doing away with it. If it could be greatly modified, then we should have something different from life as it now exists in man.

This does not mean that more will not be learned about the detailed utilization of energy by the human body. We are still in the dark about how food molecules are actually synthetised into protoplasm and just how protoplasm extracts energy from sugar or fat. A great deal of progress can be made in these bio-chemical studies that will reveal eventually these obscure details. It is a task not for the charlatan or quack but for the man with great skill and training; and when the results become known, they will not be patented but given freely to advance our knowledge of man which is the supreme aim of biological science. Until such revelations are made, one can apply what is already known about how the body satisfies its need for food energy. No one has ever made a valuable discovery in this special realm which is not known by all reputable doctors the world round. There is not a single patented food product known to the writer that yields a special brand of energy nor one that is as valuable as the natural foods.

The time has come in codifying the results of scientific discoveries when emphasis should be placed on the significance of these basal discov-

eries to mankind as a whole. It is of little value for a few learned men to know these facts and personally benefit through their application, it is a wholesale application that is most needed. The elementary understanding of the use of energy by the human body should enable man to understand easily why he cannot substitute "food" lacking in energy for food that has been his natural source of energy for thousands of years. It is, therefore, not that so much more information is needed about what makes the body go as it is the sensible application of what is abundantly testified to by every scientific investigation in metabolism.

Progress will also be made in finally grasping the significance of vitamines. These are again natural parts of natural foods. Their chemical features are still unknown and man has yet to discover their full value in his diet. When this discovery is made, we shall realize the importance of another limitation, similar to the chemical messengers, to which man has become adapted through centuries of making up his dietary from selected foods.

The chemist will continue to make new combinations of atoms and molecules that will exceed in complexity the more than two hundred thousand compounds already made, some of which even Nature has not produced. At any time he

may synthesize a product that will contain food energy for man and thus be able to supply such a need as sugar which heretofore has come only from plants. This is one of the progressive possibilities in the domain of metabolism. As marvelous as all such triumphs of the human mind are, they go no further than to help man to supply more readily an unchangeable and unmodifiable need.

The human family in one form or another antedates all human history. It had its beginning with the advent of paleolithic man. From this time until the present, a period of time for which the human mind has no adequate measure, there has been a slow change in the recognition that has been given to woman until in the higher forms of civilization the family is regarded as a sacred relation and protected by custom and law. Out of this relation one transcendent obligation has crystallized,—the sacred privilege of begetting children. This ideal is in marked contrast to that found among the followers of Islam where sexual satisfaction for man dominates.

This ideal which is a distinct feature, especially of the English-speaking races, imposes a good deal of self-restraint but in all of these changing ideals from the age of first fossil man until the present, there has been no modification of the law of biogenesis,—no substitute for the natural

method of creating a new human being. Mankind as of old is still giving off a part of his body which actually becomes transformed into his children. There is no single exception and those who would ignore this fact attempt to alter one of the most basal laws of their being.

The law of biogenesis does not admit of much progress or modification. The chief significance that it has for us should be cherished until we have come again to regard it in its simplicity and purity. Investigations in the general field of heredity will slowly reveal how parental characteristics are passed on to children but this information will not enable man to change these traits, once the embryo is formed. The studies in heredity have already indicated that certain derangements such as one form of imbecility are passed on to the offspring and there is a growing conviction in the minds of many that such facts must be recognized in the domestic relations of man and woman. When this group of facts becomes sufficiently assimilated by the people at large, restrictive laws will be passed prohibiting those who are thus afflicted from perpetuating these maladies.

This raises the whole question of the contributions of biology to the problem of producing better human beings, of exercising as much care in producing a new human animal as all careful

breeders do with their domestic animals; they have proved that it pays to select and eliminate. The Homes for Feeble-Minded and the Insane Hospitals of our Nation are crowded and yet we have not reached the state of mind where we approach this problem in any way that seeks to eliminate the cause,—to check the supply.[1]

But there is a field of progress in which nearly all are agreed and that is that man should keep his body free from sexual diseases. Mankind has taken immediate advantage of the scientific revelations in this field and made stringent legal regulations governing the methods of prevention of blindness to children from infections at birth. The next step should be to protect the mother from a similar infection with all of its attendant suffering which is mainly due to man's heedlessness and self-centered interest. No more needs to be discovered in this domain to encourage any one who will give serious thought to the problem and accept the responsibility of being a man.

Closely allied with progress in these applied fields of biogenesis is the advance that mankind is making in keeping the body free from that group of diseases that have in epidemic form destroyed thousands of animals, plants and man. The cause of these communicable diseases is well

1 There are more than two hundred thousand inmates in the Insane Hospitals of the United States. This number exceeds the total enrollment of students in our colleges and universities.

known and means of prevention have been worked out for most of them. These preventive measures are of such a character, however, that one family cannot alone successfully observe them. This is due to the simple fact that so many of the germs are carried from person to person by wind, water, or milk, environmental facts with which man is constantly in contact. A community of effort is necessary to prevent the great scourges of civilization. Much progress has been made in the more enlightened communities in reducing the death rate from diphtheria, typhoid, smallpox and tuberculosis but the devastations of the great war together with lack of care and adequate food bid fair to give some of these terrible diseases a new start and thus multiply the possibilities of communication.

In America much effort has been given to saving the babies and this intelligent work has yielded important results as the decline in death rate clearly indicates. In addition to this most worth-while application of biological science, attention should be directed to the important fact that there is a sharp increase in the death rate of adults between the 45th and 50th years, just at the time when man is at his maximum efficiency. Here is a field in which critical studies should enable us to make marked progress.

What does biology contribute to that aspect of

MAN,—THE ANIMAL which clearly separates him from the animals? It is hardly practicable to state this difference in a word or phrase such as "the mind of man," "Man's esthetic or ethical sense" because there is such a wide range of opinion among psychological and philosophical scholars as to the definition when such expressions are applied to animals and then applied to man. That the distinction between man and animals is clearly evident few will deny although it is very difficult to agree on terms that shall properly describe this difference. Much of the writing of the past fifty years is based on the philosophical assumption of the purposefulness of man and the utilitarian relation of everything else to his uses. If one accepts this postulate, then it is easy to separate those qualities in man which support such a premise and designate them as distinctive. On the other hand, if one employs the scientific method and looks for the source of those qualities which are so evident in the mind of man, then he can draw no such sharp distinctions. It is in this latter sense that the following paragraphs are written.

Man gains his information of the external world through sense organs inferior in acuteness and range to those found in some of the animals. He cannot see as well as the soaring hawk as it seeks its food by day or the silently flying owl by

night. The acuteness of hearing in dogs has been a source of wonder for a long time and their ability to follow a trail by scent is truly marvelous when compared with man's degenerating sense of smell.

Although man's sense organs do not equal those of some of the animals, they are all that he has and when supplemented by mechanical devices, enable him to become aware of more facts in his environment than can any animal.

In so far as students have been able to determine, men's sense organs are stimulated in just the same manner as the sense organs in a dog, snake or fish. There has been no discovery that permits us to place man in a class by himself in this particular.

These obvious facts long ago stimulated men to seek for some other structure that would account for the marked difference between themselves and the animals and so they have devoted much time to analyzing his cerebral hemispheres which are so conspicuous for their size. To this part of the brain all of the sense organs eventually report and they also have just the same relation in the dog or monkey. But it was early evident that man possessed more complex cerebral hemispheres than any animal but thus far this complexity is the chief structural difference that has been discovered.

It is exceedingly difficult to measure accurately a qualitative feature in a mental process but some means must be devised and when it is done this is the field in which great progress will be made. For it is really in this qualitative difference that man stands out supreme over all other living things. The quality of muscular response enables one man to out-race all competitors and we are unable to describe as yet just what this difference is. Those who assume that man possesses qualities entirely unlike those existing in the higher animals, do not have anything to explain; while those who seek for the genesis of these qualities believe if it had been possible to have studied primitive man that they would have been found to be similar to those in the animals.

In their attempt to work out a scientific explanation, scholars have started with such universal features as self-protection, the securing of food and reproduction. Just at present it is popular to ridicule the Freudian school of psychologists who make the reproductive reflexes the center of their genetic scheme in explaining the mind of man. This theory like many others suffers from its too enthusiastic supporters but in a few years it will take a more conservative form and be recognized as an important step in solving one of the most difficult biological problems. One of its chief weaknesses is that it makes one of the funda-

mental characteristics of life dominate over all others instead of being co-equal. Until the significance of the food-getting reflexes and the self-protective reflexes are as critically analyzed as that of the reproductive reflexes and the whole united into one general process, after we come to understand the appropriate stimuli for these processes, we shall not have made an adequate study of the origin of the mind of man.

There is great promise of progress in this field in the coming years. Already we have discovered much that is similar in the way that man and animals learn with animals quickly reaching their limit but with man ever extending his limits.

In this brief sketching of some of the more probable fields of progress which will give a better understanding of man, no revolutionary changes are anticipated nor is it suggested that fundamental laws will be altered. Progress must rather be in conformity with those principles which clearly indicate that we must recognize the ineradicable influence of heredity and that the right to be well-born has a scientific foundation; that good food and a wholesome environment play an important part in well being; that the period of natural growth cannot be shortened nor the days of mankind lengthened; and that mankind cannot ignore nor set aside these basal relations.

Such a study as this aims to bring out the significant fact that all living things are definitely organized and that the term organism usually applied to them has an important meaning. This organization appears to have come into existence with the first form of living protoplasm and remained as the most conspicuous feature of all subsequent forms of life. When the molecules of protein took on the protoplasmic pattern a new organization was created that has always remained distinct and yet an intimate part of the material universe.

This knowledge which man has gradually accumulated through long years of study does enable him to direct his affairs more intelligently than his ancestors who found their way by experimentation. He now understands that he cannot ignore the basal laws of the material universe nor those that regulate his own being but that he can anticipate these laws and by the proper utilization of force rise above them as in the aeroplane where he employs a force stronger than gravity.

But in all of this wonderful progress man has never been able to free himself from his animal relations. In all of the progress of the future, he will have to give due heed to these same factors. It would seem as if the wisest course were to properly understand just what limitations Nature

has placed and then shape one's activities accordingly. To go through life largely ignorant of the laws governing mankind is like trying to enjoy a stroll in field and wood ignorant of all life about. It is seen and felt but not understood and such is man's attitude toward himself until his education gives him a grasp of the regulations and restrictions within which he lives.